ARMY RESEARCH LABORATORY

ARL Experimental Facility 108 A/B Blast Tests – Summary Report

by Neil M. Gniazdowski

ARL-MR-511 April 2001

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Army Research Laboratory
Aberdeen Proving Ground, MD 21005-5066

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ARL Experimental Facility 108 A/B Blast Tests – Summary Report

Neil M. Gniazdowski
Weapons and Materials Research Directorate, ARL

Abstract

The Impact Physics Branch of the Terminal Effects Division of the Weapons and Materials Research Directorate (WMRD), U.S. Army Research Laboratory (ARL), was tasked by the Armor Mechanics Branch, WMRD, ARL, to perform blast measurements in ARL Experimental Facility 108 A/B. This memorandum report briefly summarizes the results of four blast tests that were conducted on 8 November 1999. The purpose of this test program was to measure the blast pressure exhibited on various walls of the experimental facility's chamber (108A) as a result of the detonation of various size spheres of Detasheet and to determine the maximum explosive weight that could be used in this facility without extensive modifications.

Acknowledgments

The author would like to thank Carl Paxton, Sterling "Doc" Shelley, Donald Little, and Vaughn Torbert for their expert assistance during these tests.

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1. Introduction

The Impact Physics Branch of the Terminal Effects Division of the Weapons and Materials Research Directorate (WMRD), U.S. Army Research Laboratory (ARL) was tasked by the Armor Mechanics Branch, WMRD, ARL, to perform blast measurements in ARL Experimental Facility 108 A/B. This memorandum report briefly summarizes the results of four blast tests that were conducted on 8 November 1999. The purpose of this test program was to measure the blast pressure exhibited on various walls of the experimental facility's chamber as a result of the detonation of various size spheres of Detasheet and to determine the maximum explosive weight that could be used in this facility without extensive modifications.

2. Test Setup

Hand-formed Detasheet spheres were detonated on top of a target table 57 in away from the entrance door of the chamber. Again, it should be noted that the Detasheet spheres used were handpacked and not cast, but they were considered adequate for the purpose of this study. An RP 87 detonator was used to detonate the explosive. The detonator was placed in the center of the explosive and was positioned facing toward the door of the chamber. This was done to ensure that the maximum pressure obtained by the detonation was aimed at the door and that the majority of the fragments from the detonator were propelled away from the pressure gauge mounted on the door. The door to the chamber is made of 1/2-in steel and has a 1/2-in bar stock locking pin, which is shown in Figures 1 and 2. Figure 3 shows a PCB 102M230 pressure gauge mounted into a lead "pig" pressure mount, which is attached to the chamber door facing the inside of the chamber. This pressure gauge was mounted so that it was in the direct line of sight of the explosive. The distance between the center of initiation and the pressure gauge was 72 in. (Figure A-1 in the Appendix shows a schematic of this pressure transducer. Figure A-2 lists the operating specifications of this transducer model. Figure A-3 is an engineering drawing of the lead pig pressure transducer mount.) A second PCB 102M230 pressure gauge in a lead pig mount was placed at the opening of a vent located on the sidewall of the chamber. This location was selected because the walls of the vent are constructed out of sheet metal. It was feared that this duct would be ruptured or severely damaged from the blast waves. The vent has a 1-ft^2 opening. Figure 4 shows the pressure gauge and lead pig mount at the entrance of the vent. (Calibration curves for both

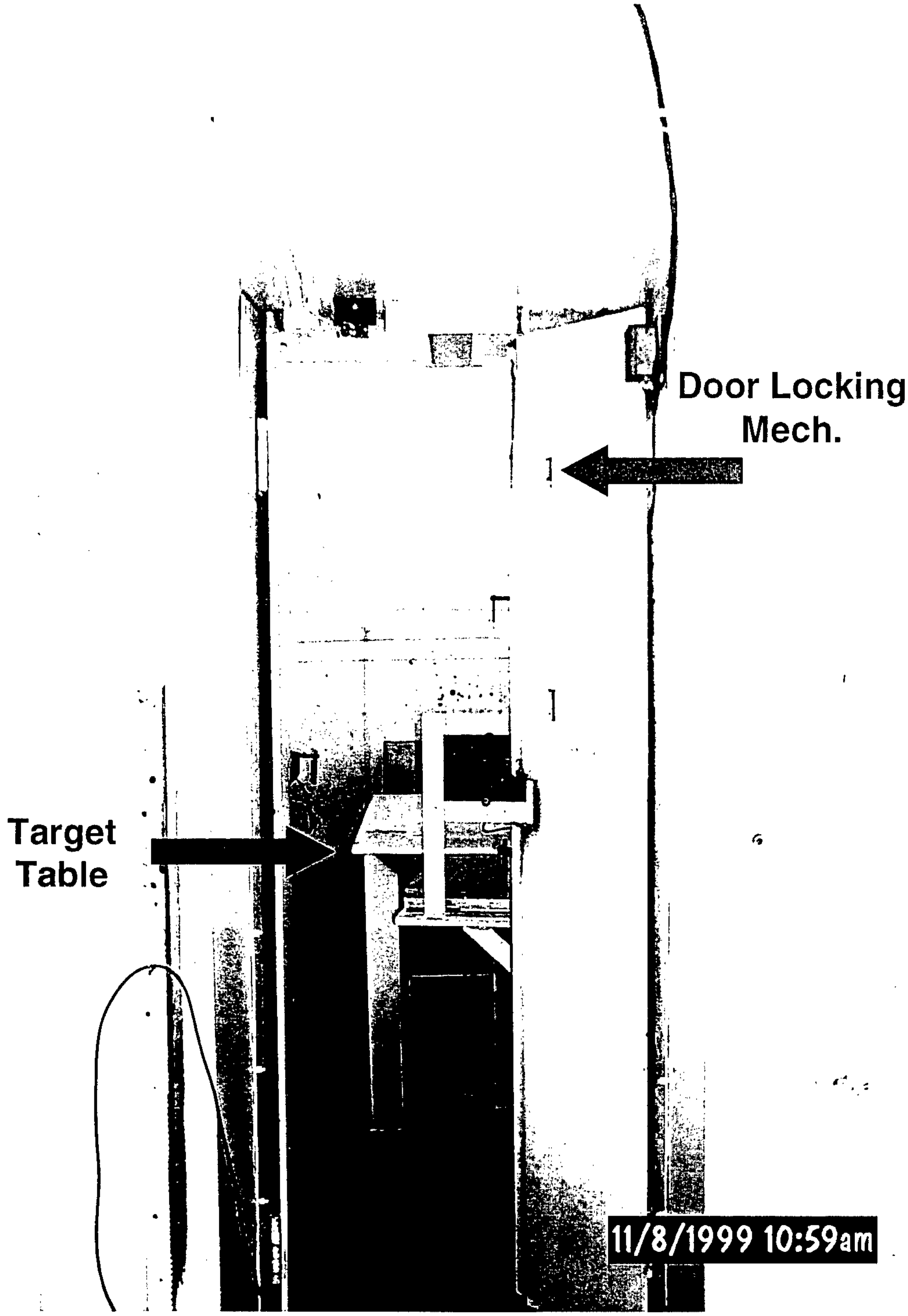

Figure 1. Photograph of entrance to chamber showing locking mechanism and target stand.

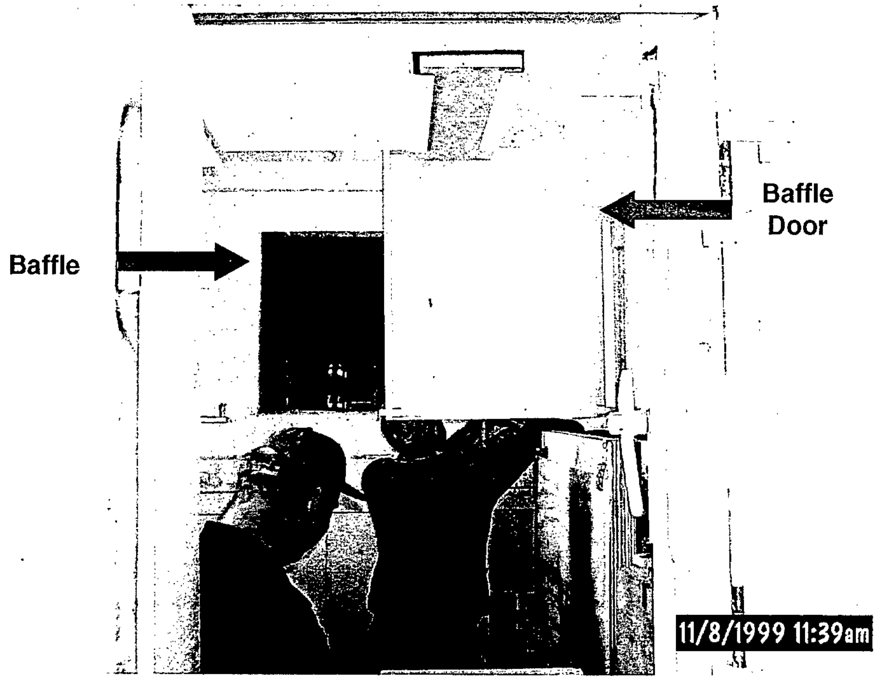

Figure 2. Photograph of chamber showing locking mechanism and baffle opening.

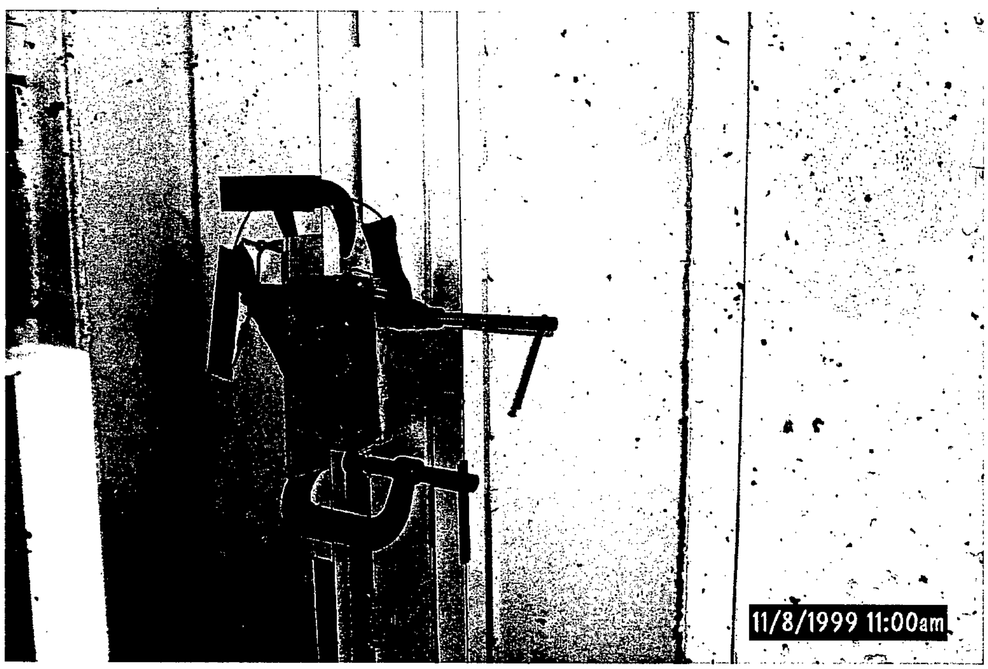

Figure 3. Photograph of pressure gauge and mount clamped to entrance door.

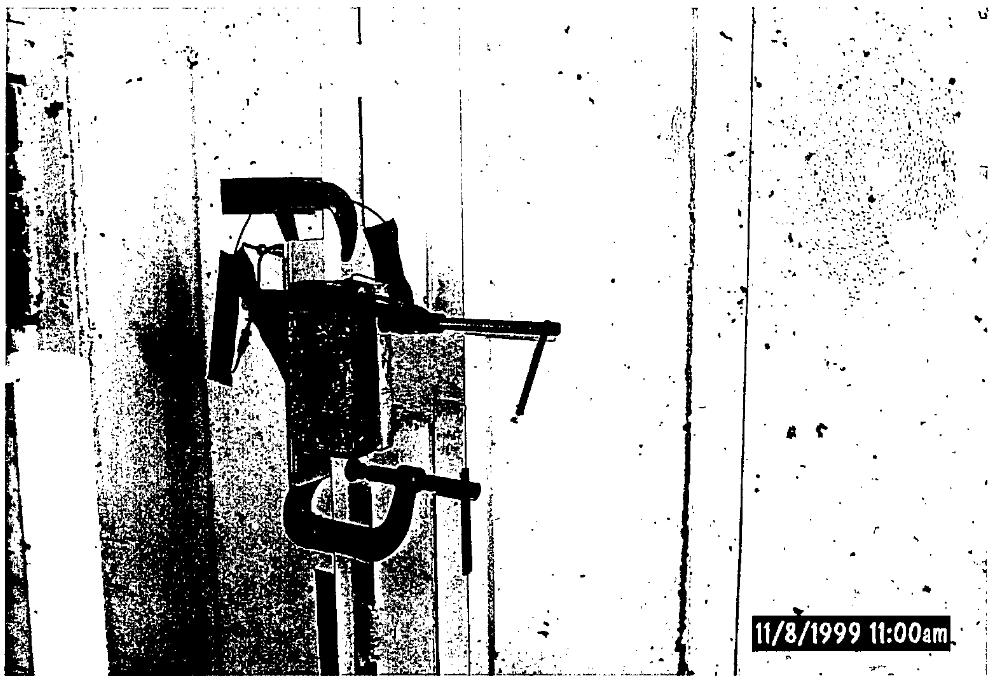

Figure 4. Photograph of pressure gauge and mount at entrance to vent.

pressure transducers can be found in Figures A-4 and A-5.) Figure 5 shows the approximate layout of the chamber with dimensions. The approximate volume of the chamber is 669 ft^3. The chamber has an additional baffle that can be opened. This baffle has a 107-ft^2 opening and is shown in Figures 2 and 6.

Two Lecroy LT344 500-MHz oscilloscopes were used to capture the data obtained in these tests (Figure 7). Data were sampled at 1 μs per point for a duration of 190 ms. The 190-ms duration was used to enable the signal to return to baseline as much as possible, which gives us an idea of the venting rate for the chamber. Two plots for each signal are given in section 3. The first time history is a full-duration plot to show how the pressure levels change with time. The second time history plot is a short-duration plot of the initial pressure wave measured and the initial reflected waves that were seen shortly after. It should be noted that all of the measurements shown herein are reflected pressure. The impulse of the pressure measurements obtained on the door were calculated for the first blast wave that struck the door. Impulses from secondary reflections were not considered. In all, four blast tests were conducted.

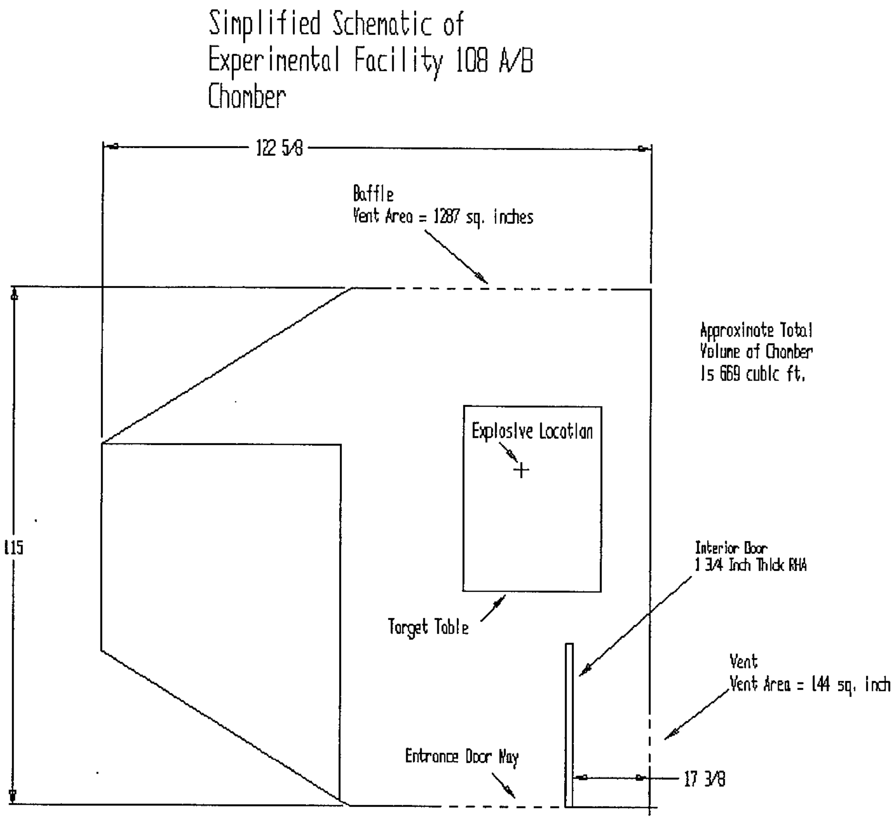

Figure 5. Schematic of Experimental Facility 108 A/B chamber.

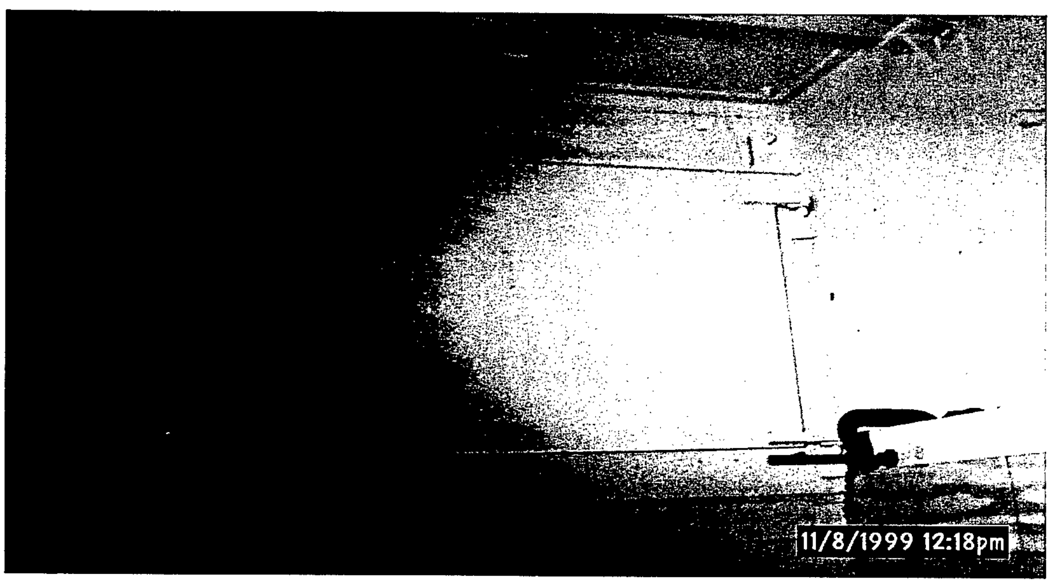

Figure 6. Photograph of steel baffle door.

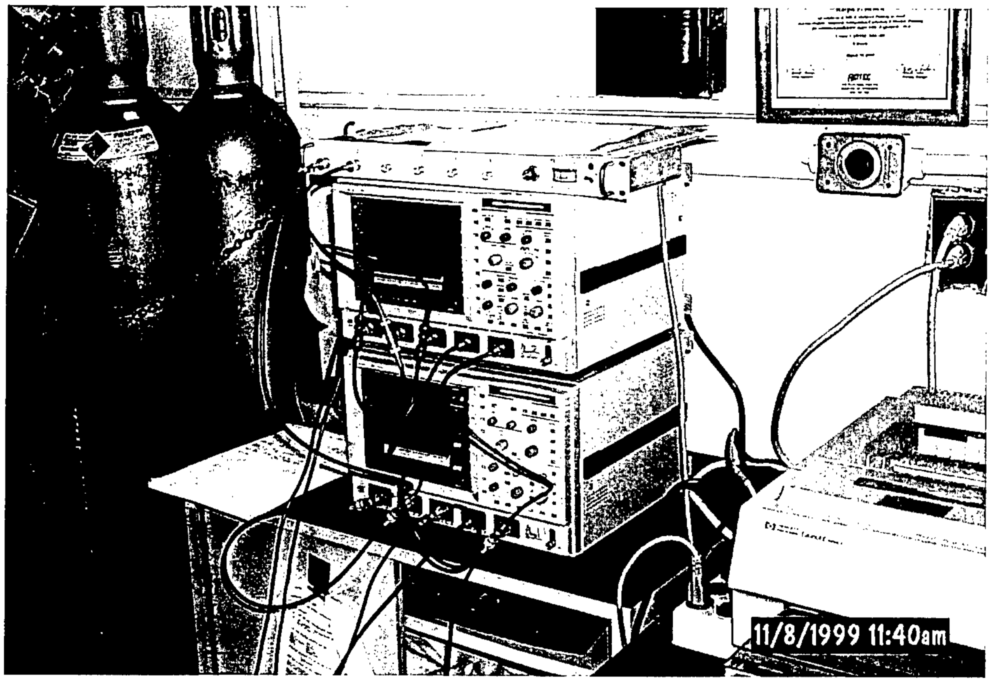

Figure 7. Photograph of data acquisition equipment.

3. Results

In test no. 1, a 10-g sphere of Detasheet was detonated. The 107-ft^2 steel baffle door was closed, which is shown in Figure 6. Time histories from the gauges are shown in Figures 8–11. Table 1 summarizes the peak pressures obtained in all of the tests. A maximum pressure of 10.1 psi was measured on the door with an impulse of 2.2E-3 psi · s. Figure 12 shows the impulse of the initial pressure wave striking the door of the chamber. A maximum pressure of 2.1 psi was measured at the entrance to the vent. No damage was done to the chamber.

In test no. 2, a 20-g sphere of Detasheet was detonated. Again, the baffle door was closed for this test. Time histories from the gauges are shown in Figures 13–16.

A maximum pressure of 14.1 psi was measured on the door with an impulse of 3.4E-3 psi · s. Figure 17 shows the impulse of the initial pressure wave striking the door of the chamber. A maximum pressure of 3.5 psi was measured at the entrance to the vent. No damage was done to the chamber.

In test no. 3, a 50-g sphere of Detasheet was detonated. The baffle door was open for this test. Time histories from the gauges are shown in Figures 18–21.

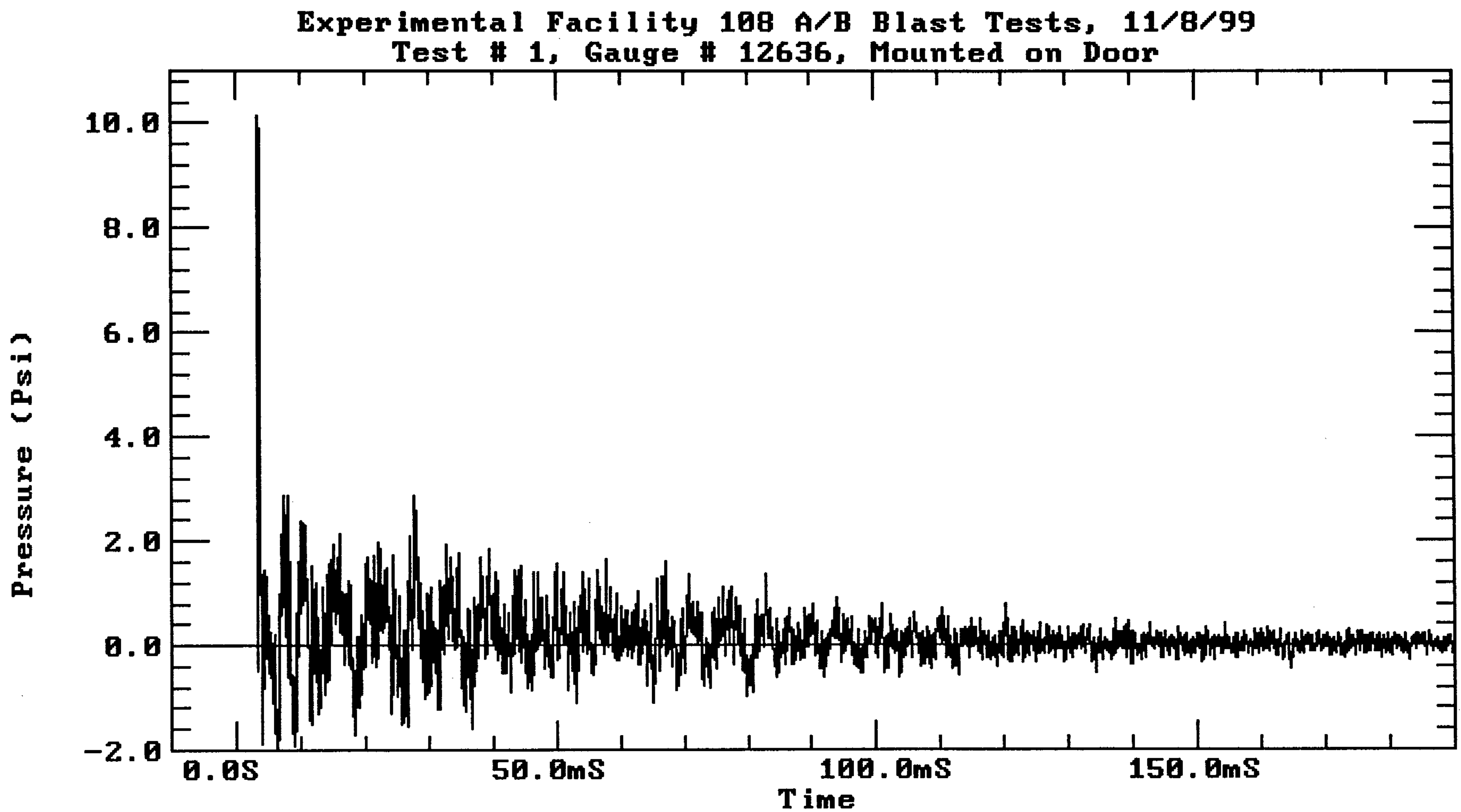

Figure 8. Test 1 long duration time history of pressure gauge mounted on door.

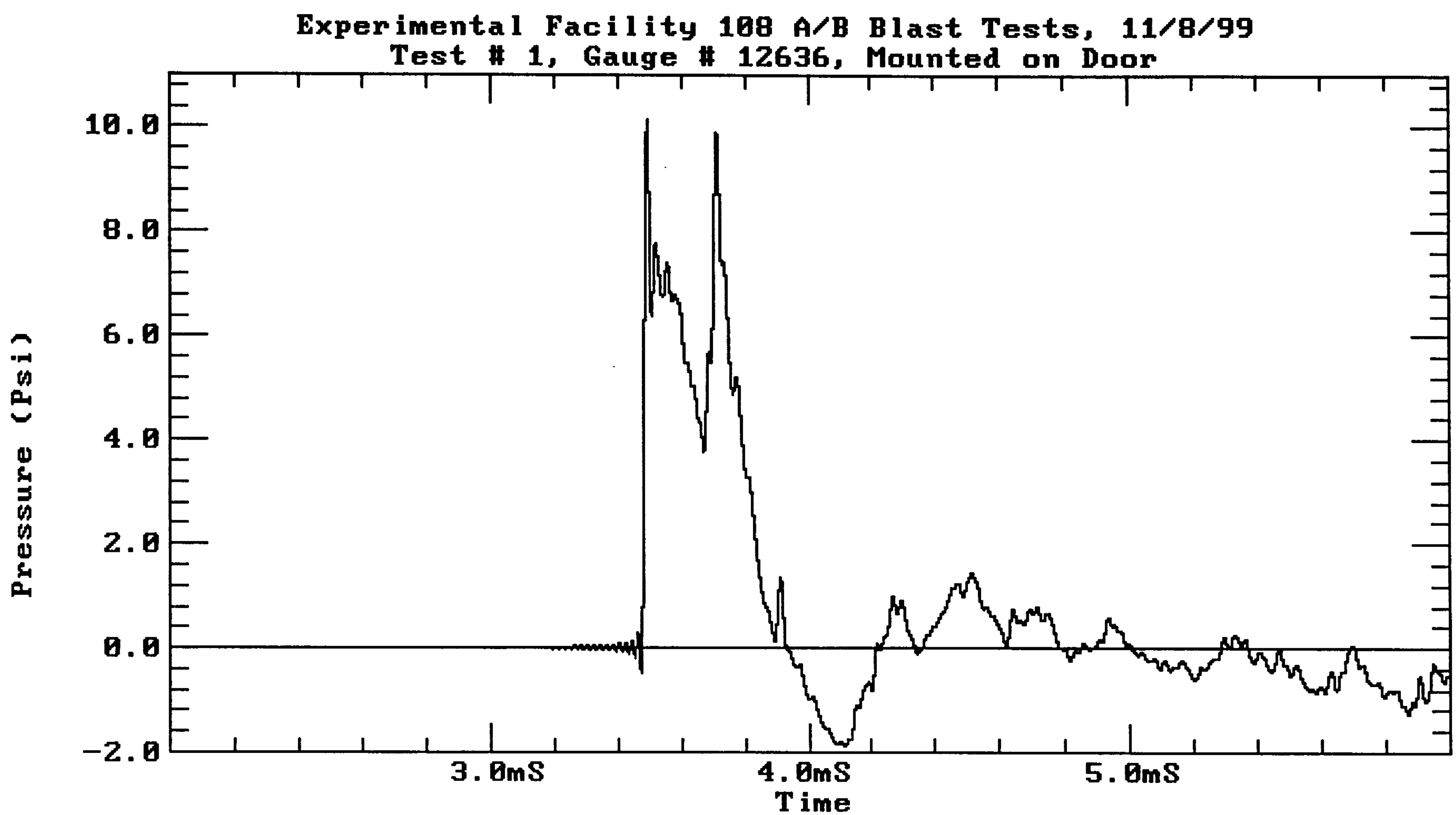

Figure 9. Test 1 short duration time history of pressure gauge mounted on door.

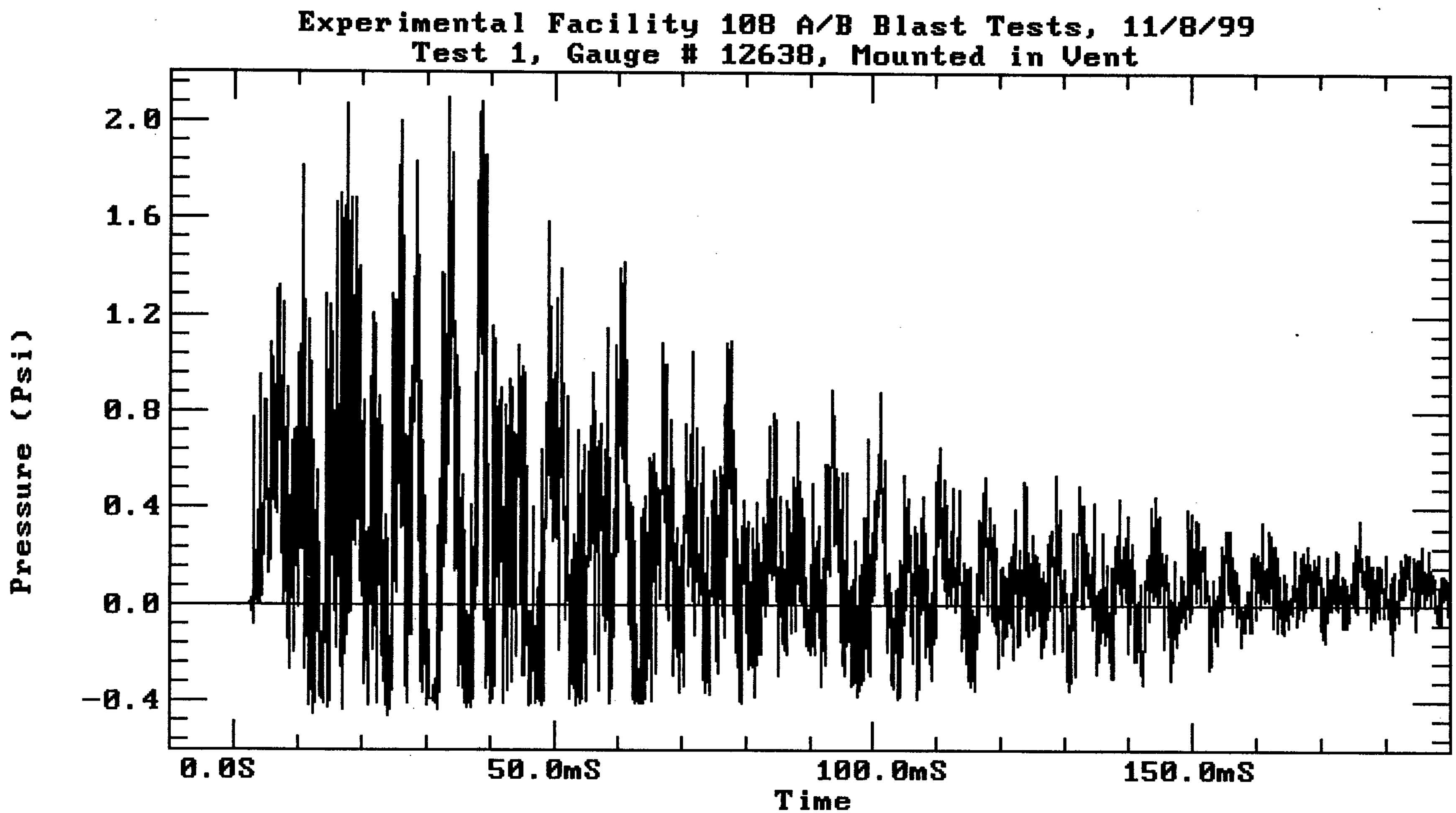

Figure 10. Test 1 long duration time history of pressure gauge mounted in vent.

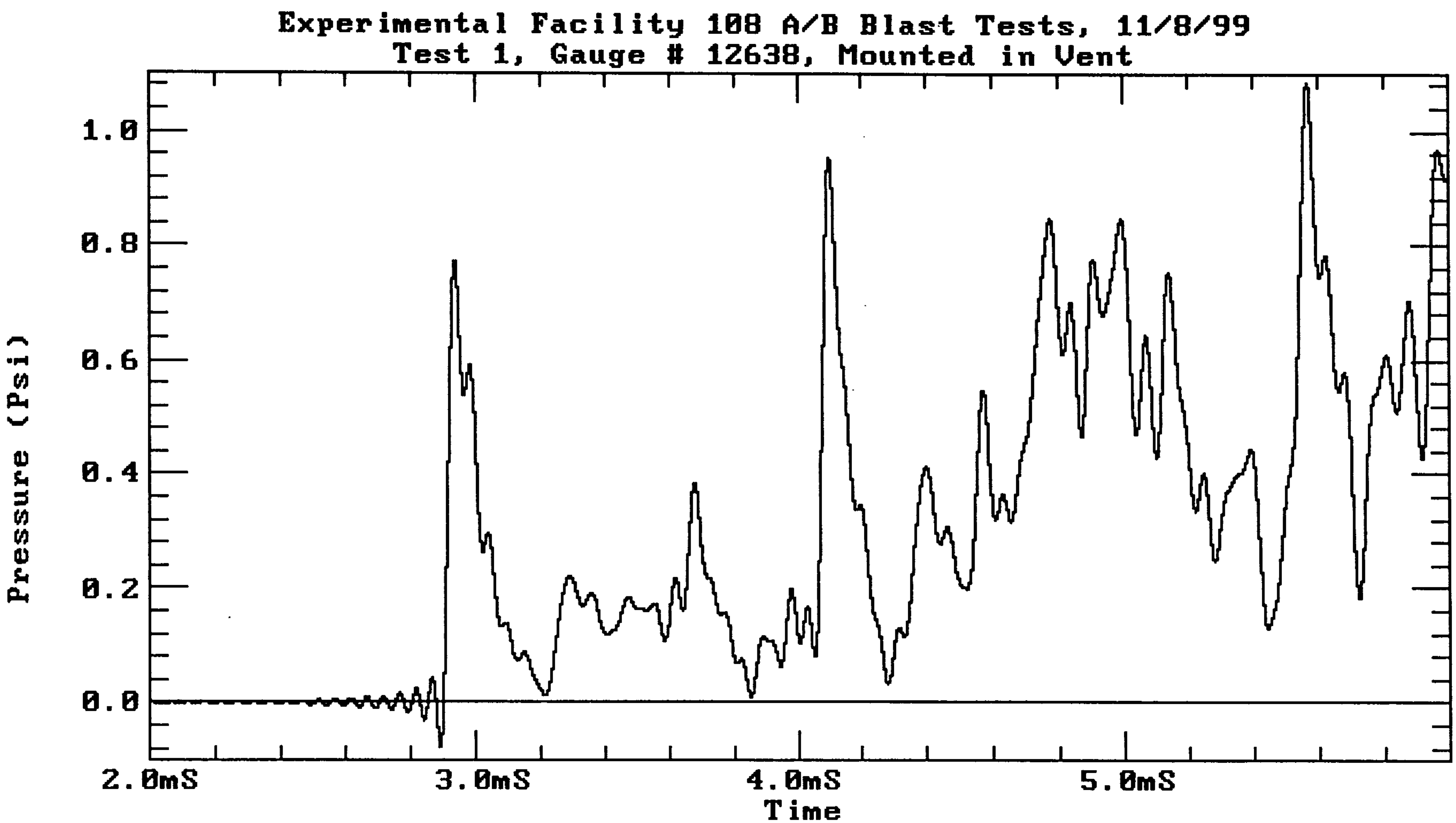

Figure 11. Test 1 short duration time history of pressure gauge mounted in vent.

Table 1. Experimental Facility 108 A/B blast study.

Test No.	Explosive Weight (g)	Pressure on Door (psi)	Impulse on Door (psi · s)	Pressure in Vent (psi)
1	10	10.1	2.2E-3	2.1
2	20	14.1	3.4E-3	3.5
3	50	30.5	6.4E-3	5.4
4	35	24.2	4.8E-3	5.1

A maximum pressure of 30.5 psi was measured on the door with an impulse of 6.4E-3 psi · s. Figure 22 shows the impulse of the initial pressure wave striking the door of the chamber. A maximum pressure of 5.4 psi was measured at the entrance to the vent. In this test, the pin locking mechanism for the chamber door was severely bent as shown in Figures 23 and 24.

In test no. 4, a 35-g sphere of Detasheet was detonated. Again, the baffle door was open for this test. Time histories from the gauges are shown in Figures 25–28.

A maximum pressure of 14.1 psi was measured on the door with an impulse of 3.4E-3 psi · s. Figure 29 shows the impulse of the initial pressure wave striking the door of the chamber. A maximum pressure of 3.5 psi was measured at the entrance to the vent. In this test, a c-clamp was used to temporarily secure the chamber door. The c-clamp was knocked loose during the detonation, but no other damage was found in the chamber.

4. Conclusions

A maximum allowable explosive weight for this chamber should be less than 50 g of explosive unless modifications are made to the chamber door locking mechanism and other critical areas. No damage was seen at 35 g of explosive with the baffle open. The door should be secured with the locking mechanism instead of a c-clamp. Peak pressures at the vent were relatively low—especially the initial blast wave that was seen at the entrance to the vent. Over time, the peak pressure ramped up due to multiple reflections and the establishment of a quasi-static over pressure. The maximum pressure at the vent was 5.4 psi, but it should be noted that the vent is partially blocked by a steel interior door.

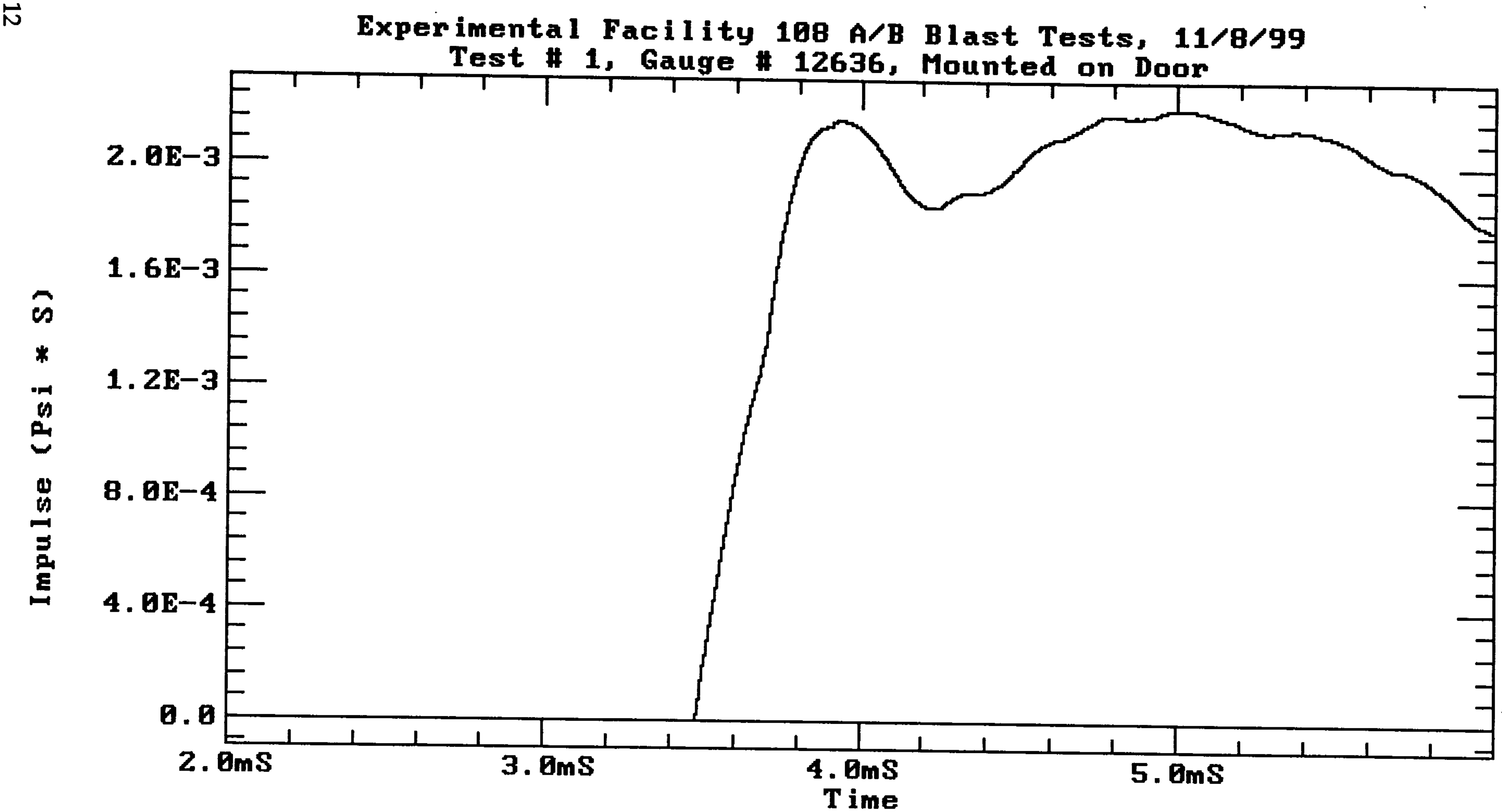

Figure 12. Test 1 impulse measured at the door.

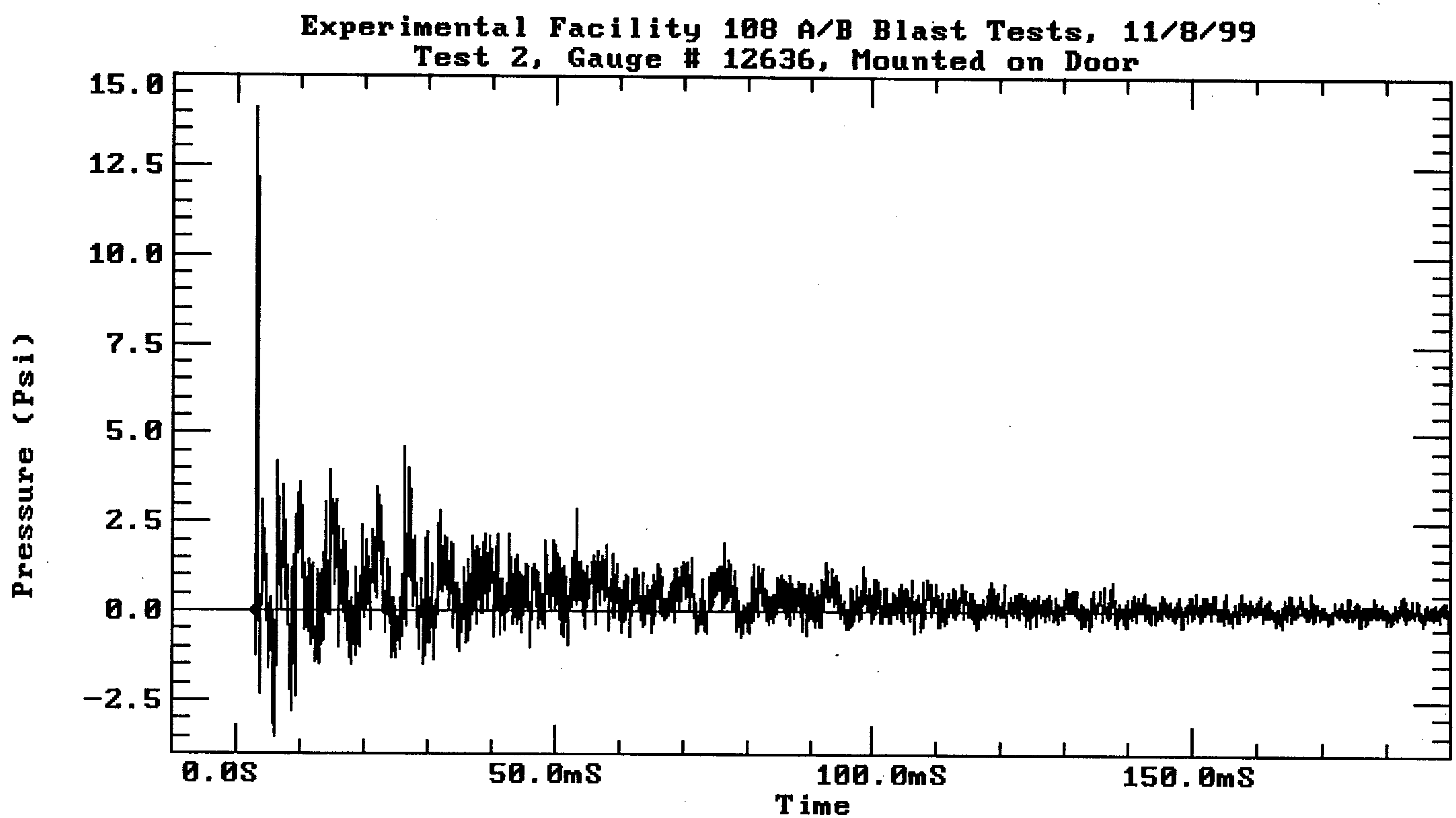

Figure 13. Test 2 long duration time history of pressure gauge mounted on door.

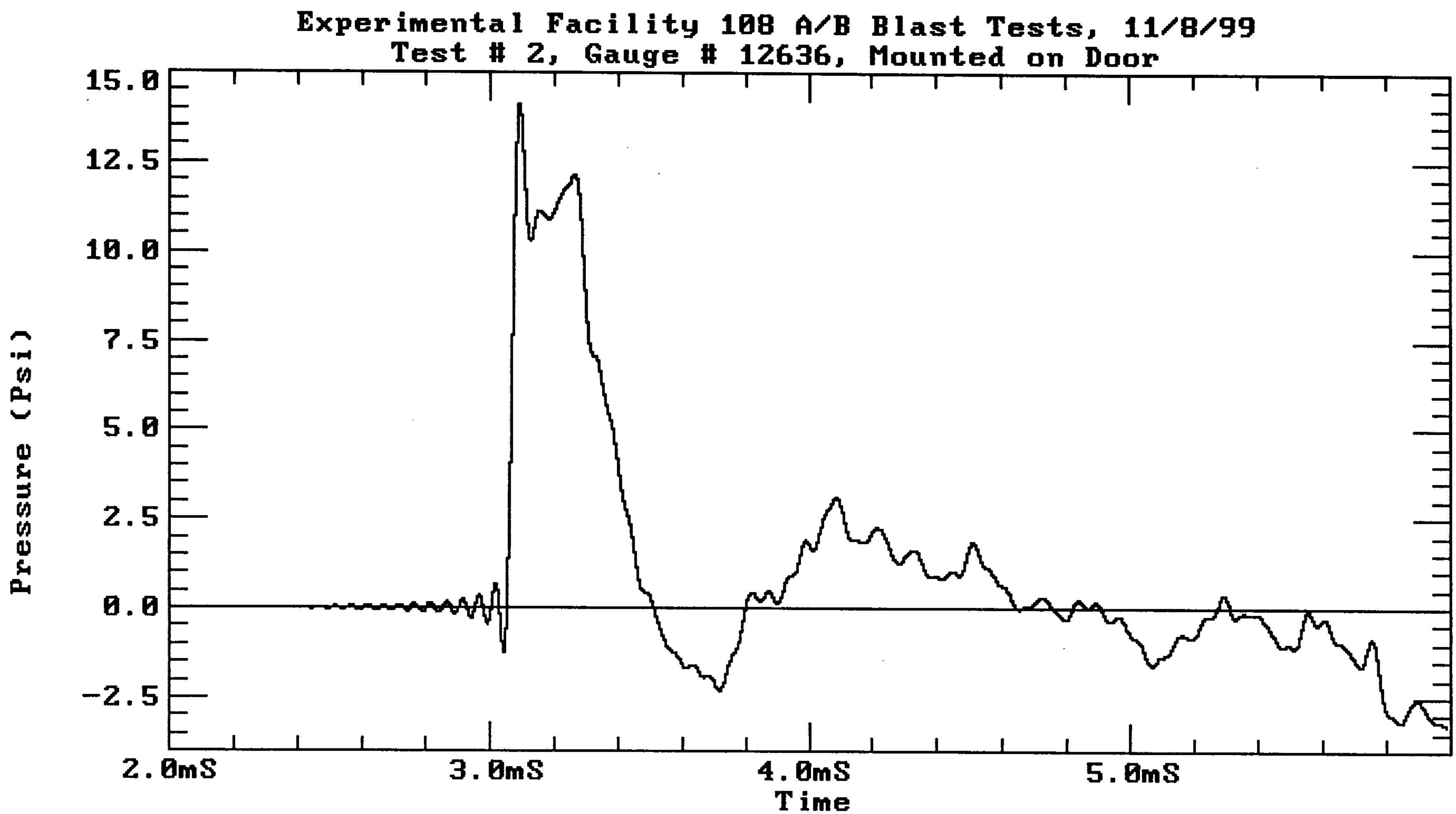

Figure 14. Test 2 short duration time history of pressure gauge mounted on door.

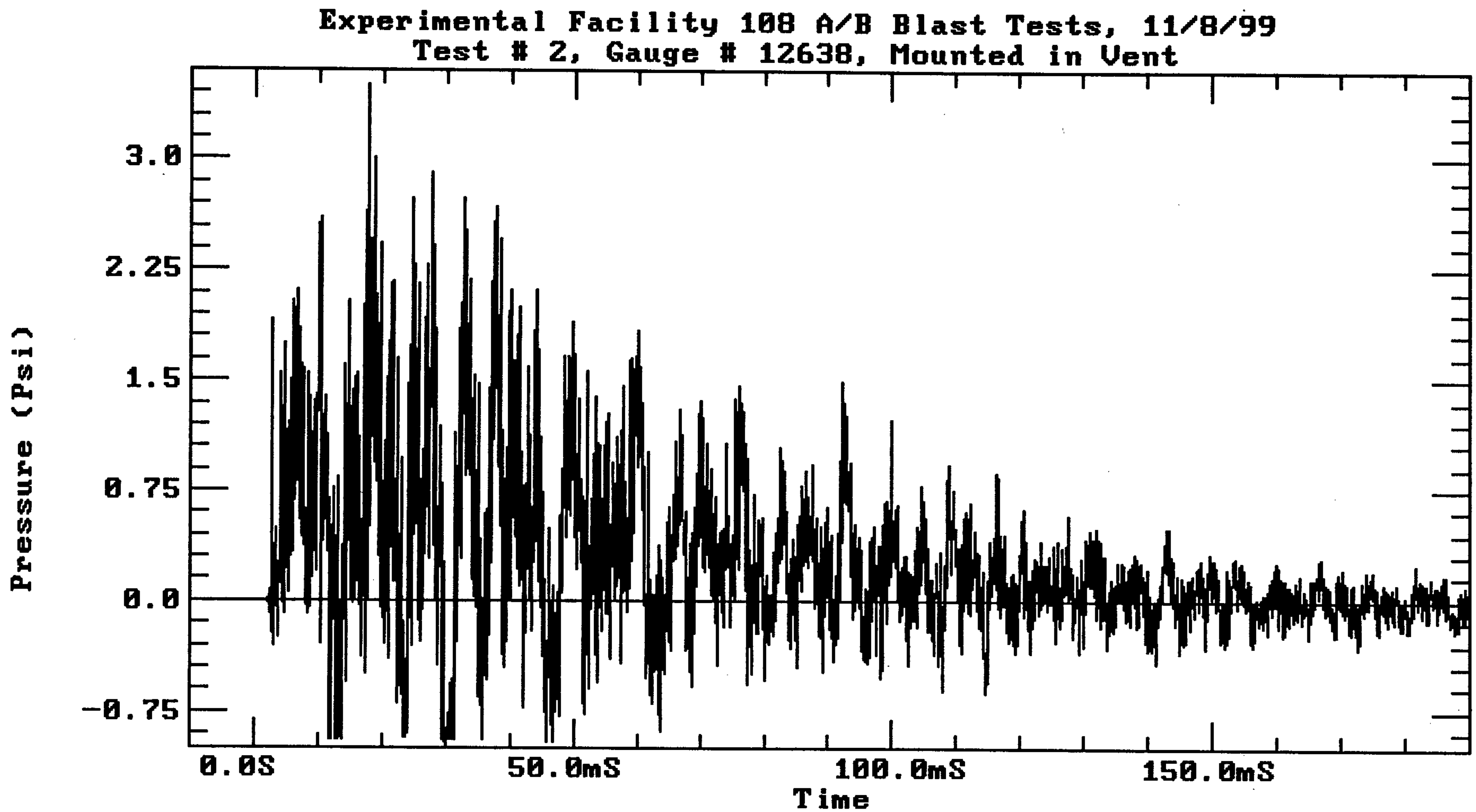

Figure 15. Test 2 long duration time history of pressure gauge mounted in vent.

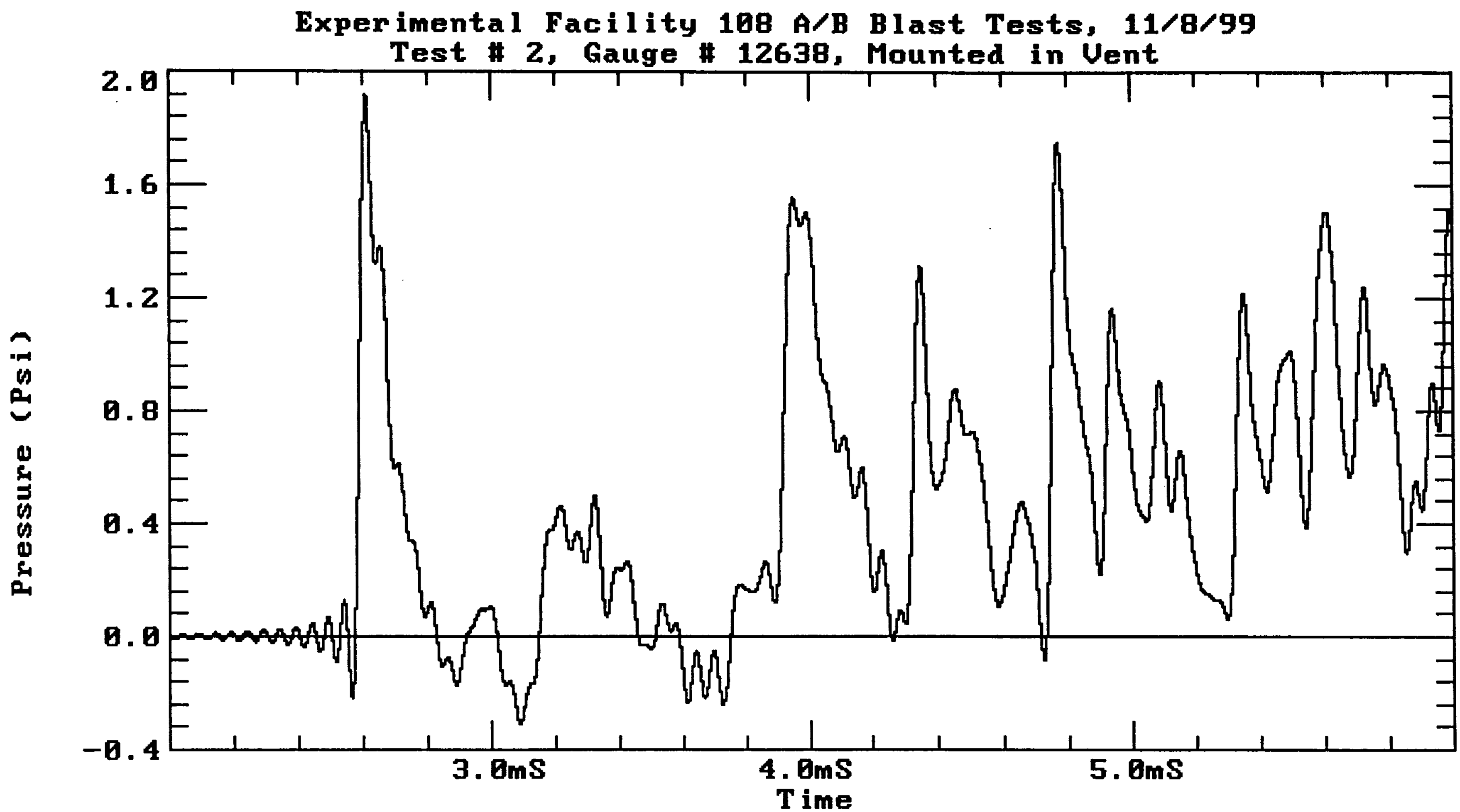

Figure 16. Test 2 short duration time history of pressure gauge mounted in vent.

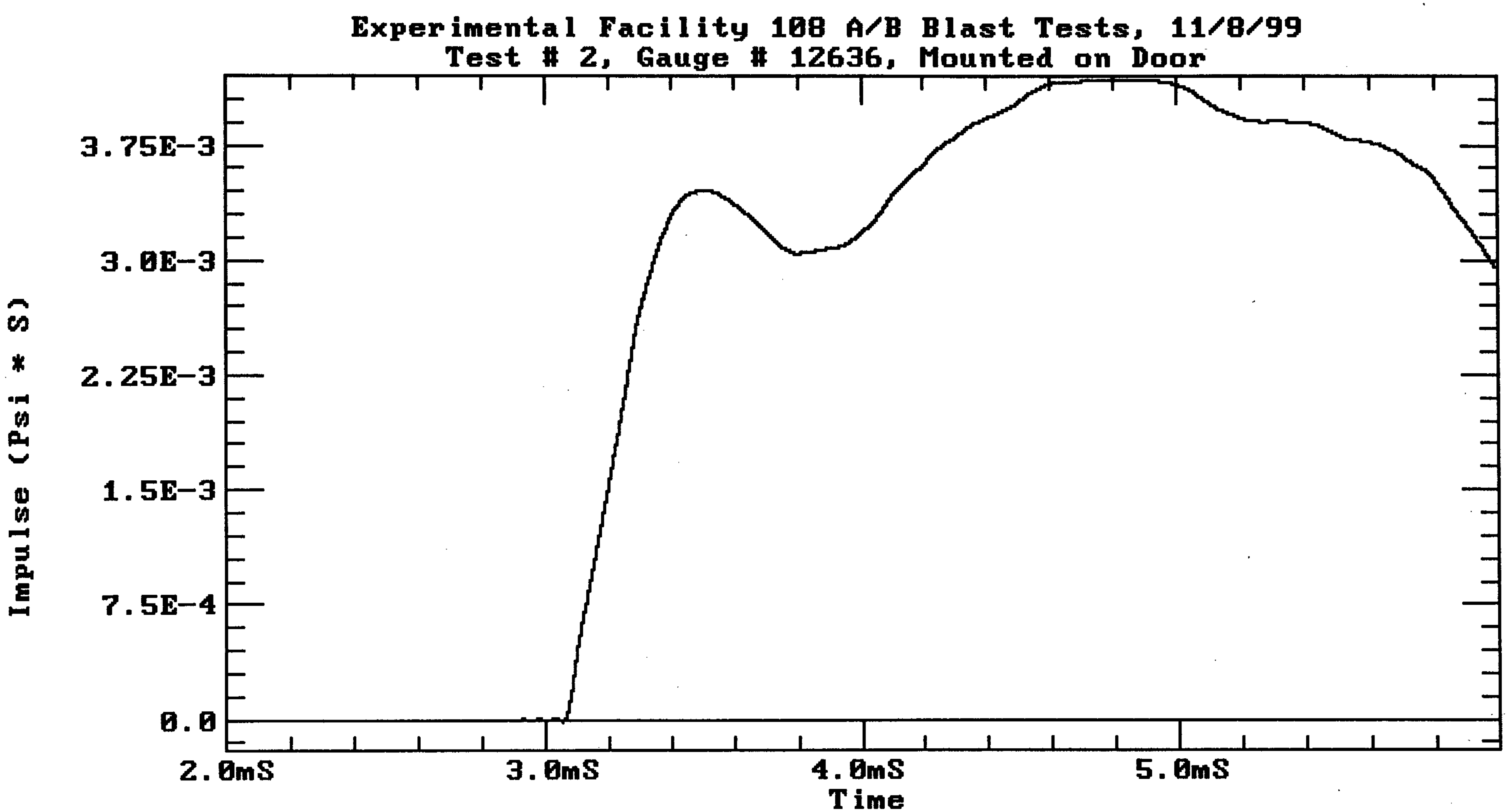

Figure 17. Test 2 impulse measured at the door.

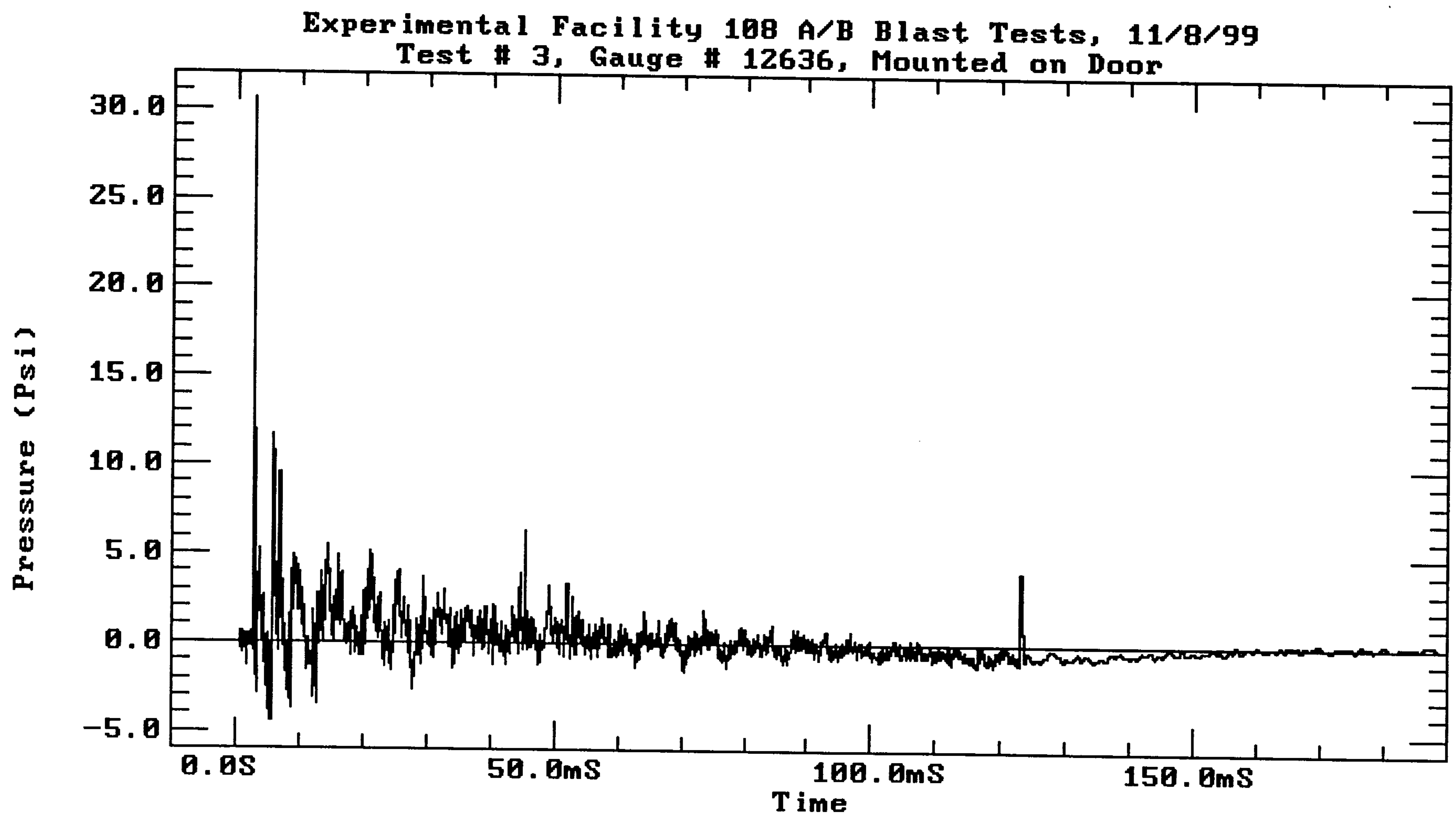

Figure 18. Test 3 long duration time history of pressure gauge mounted on door.

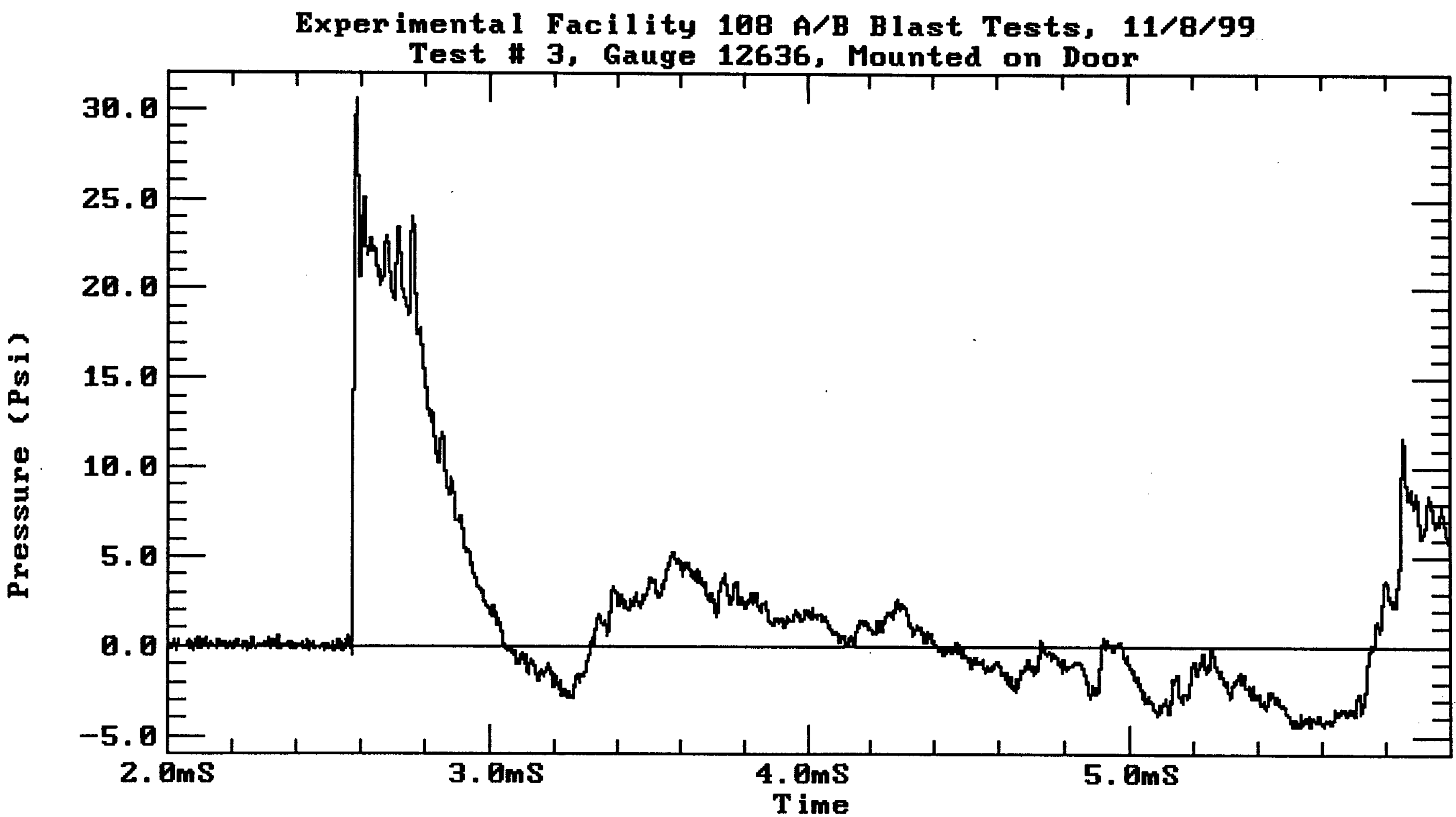

Figure 19. Test 3 short duration time history of pressure gauge mounted on door.

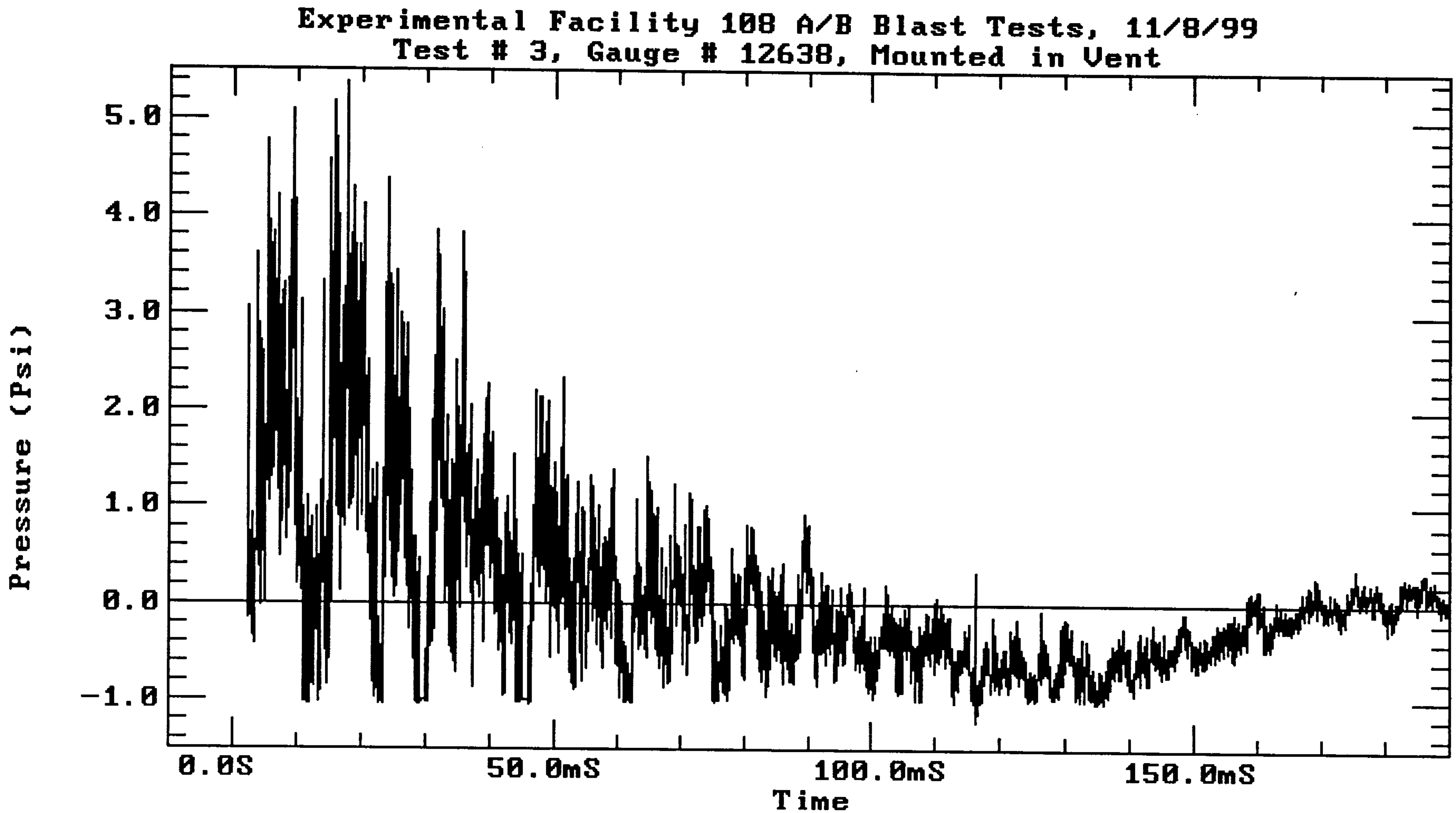

Figure 20. Test 3 long duration time history of pressure gauge mounted in vent.

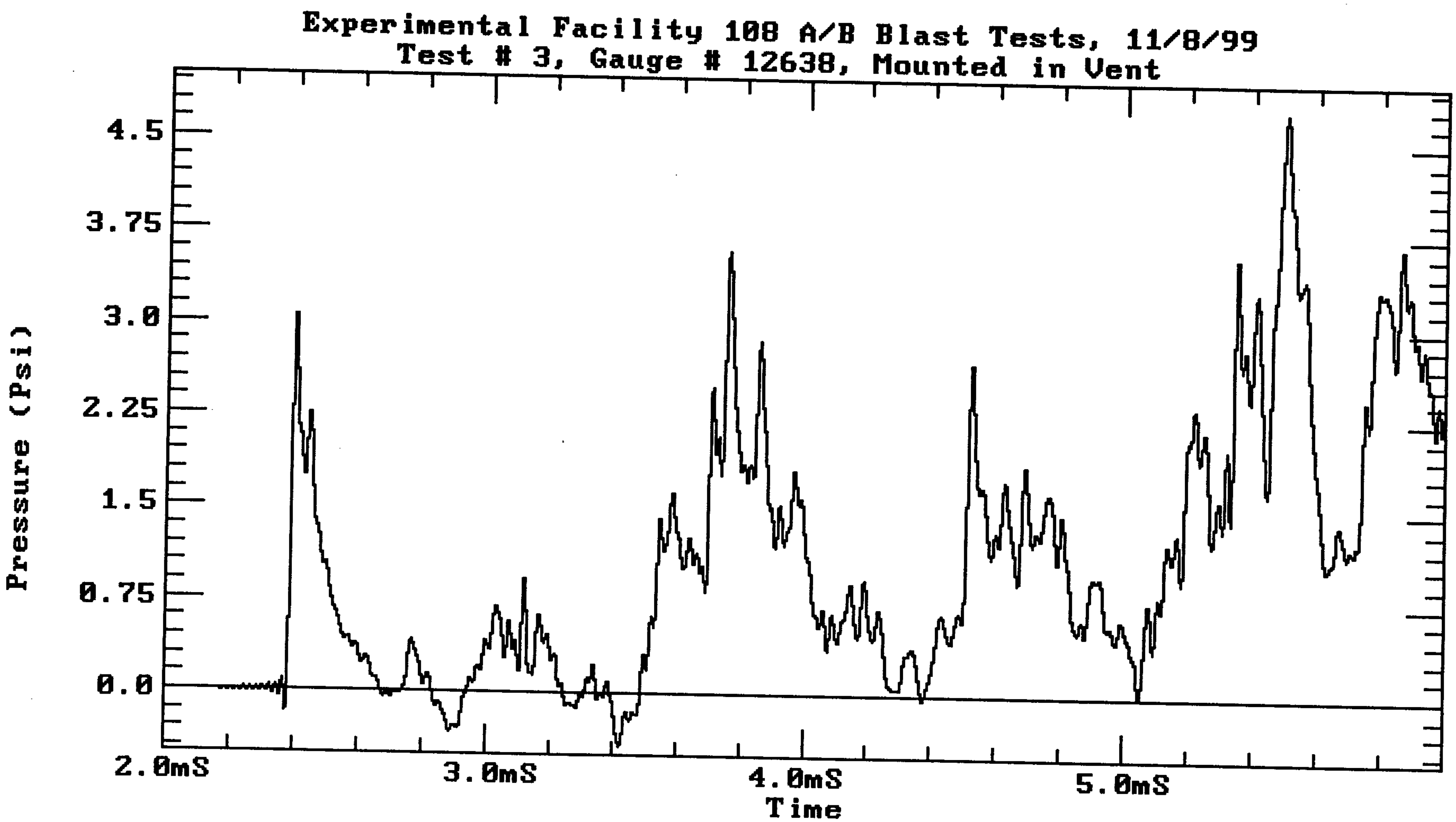

Figure 21. Test 3 short duration time history of pressure gauge mounted in vent.

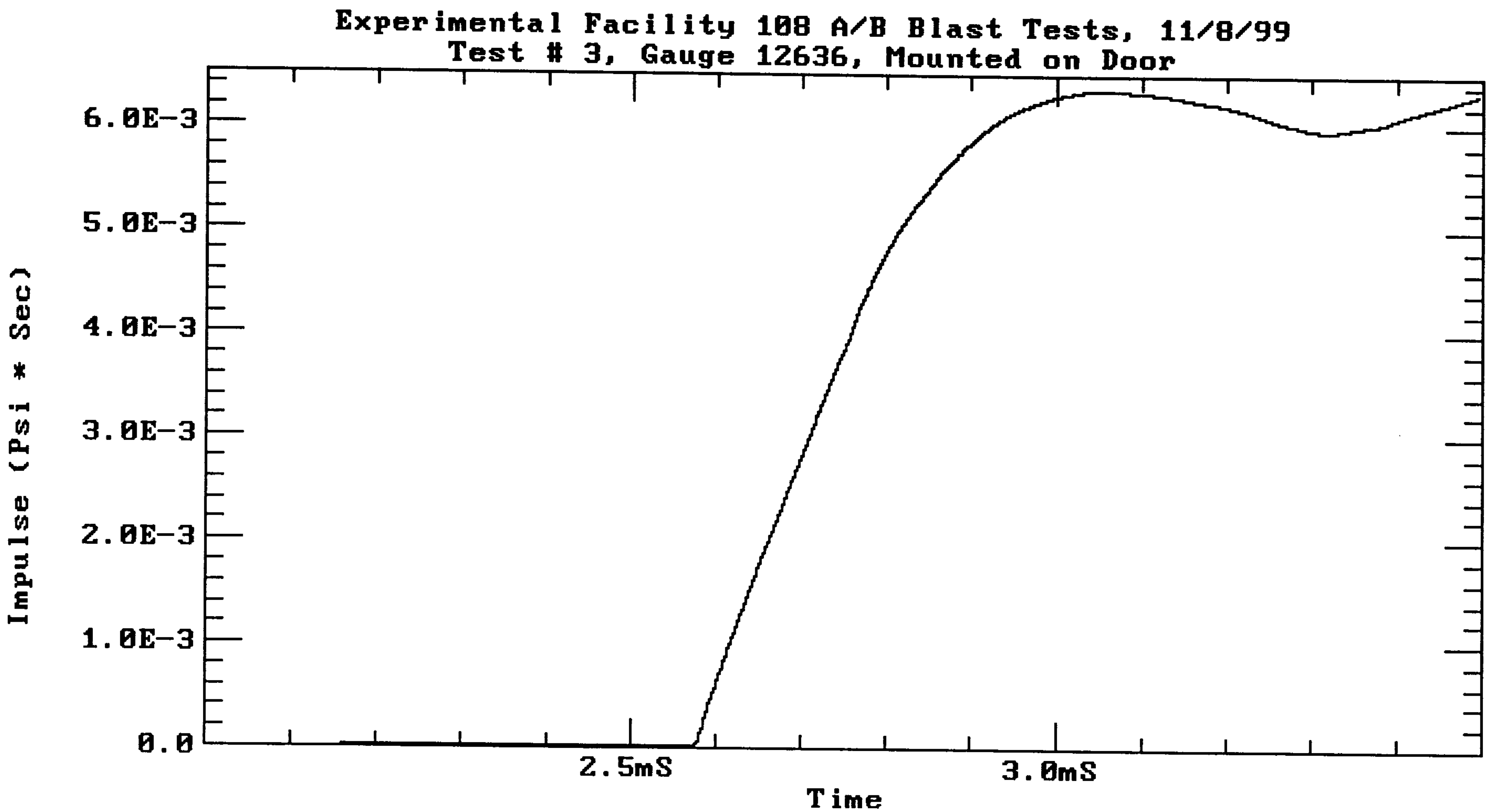

Figure 22. Test 3 impulse measured at the door.

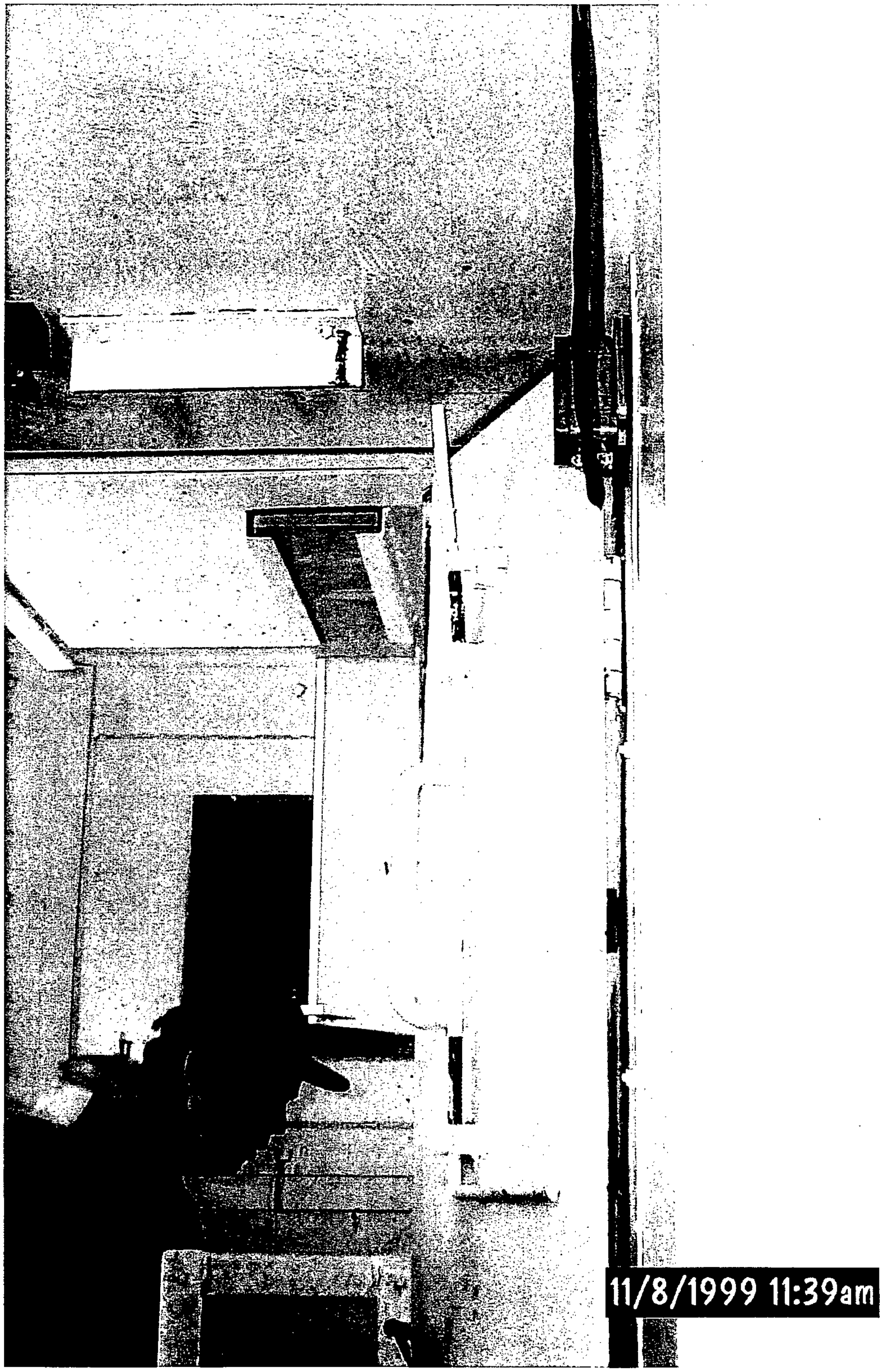

Figure 23. Photograph of door with damaged locking mechanism.

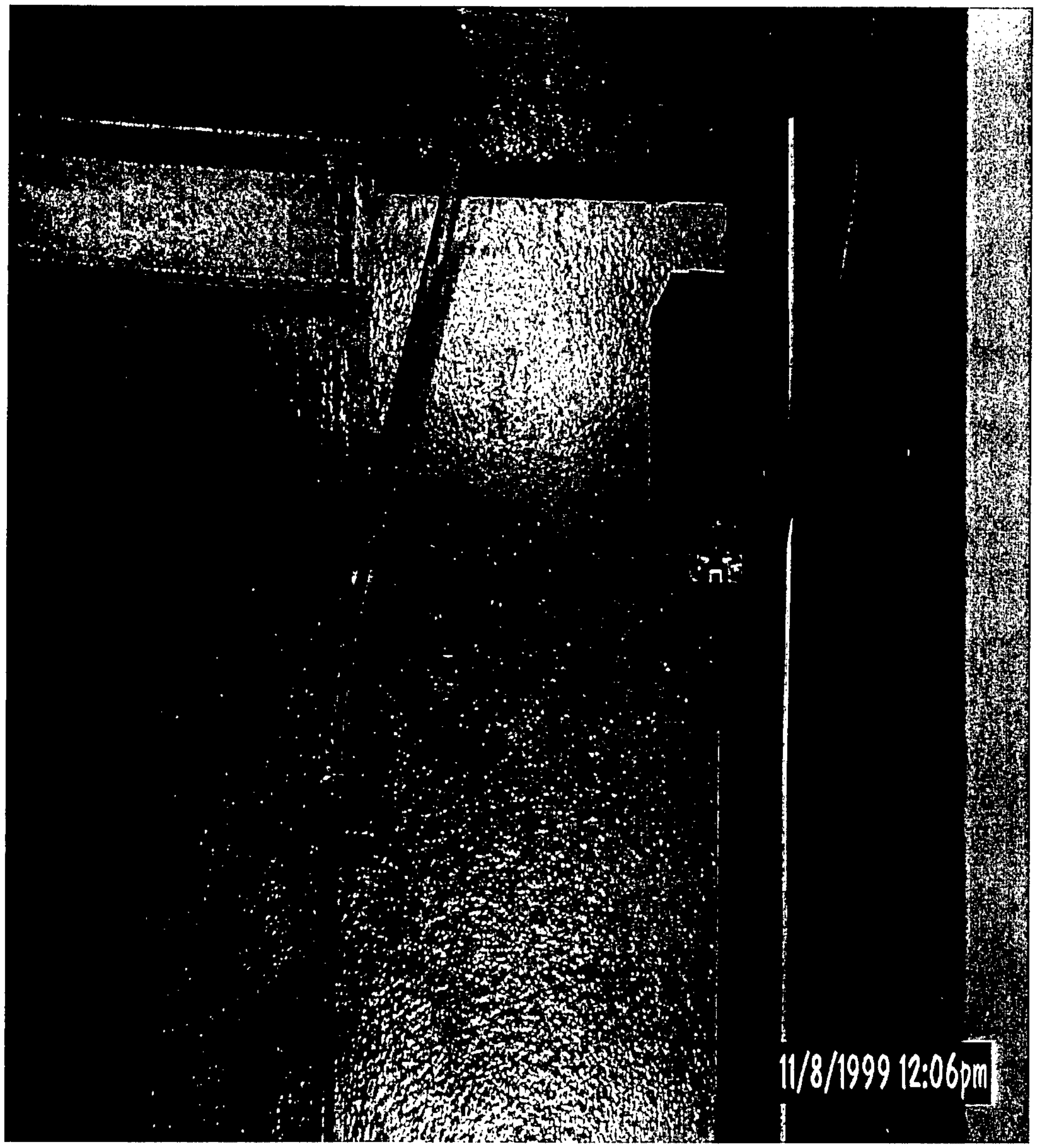

Figure 24. Close-up photograph of damaged locking mechanism.

Figure 5 shows the position of this door relative to the vent and explosive. No damage was seen in the vent during any of the tests but the vent was protected somewhat by the lead pig pressure mount and the interior door. Assuming this door is kept in the position shown in Figure 5, during most tests, the vent should be safe. However, it would be advisable to examine this vent to ensure that repeated use does not have a cumulative damage effect on its structural integrity. Once again, Table 1 summarizes all of the peak pressures and impulses measured in these tests.

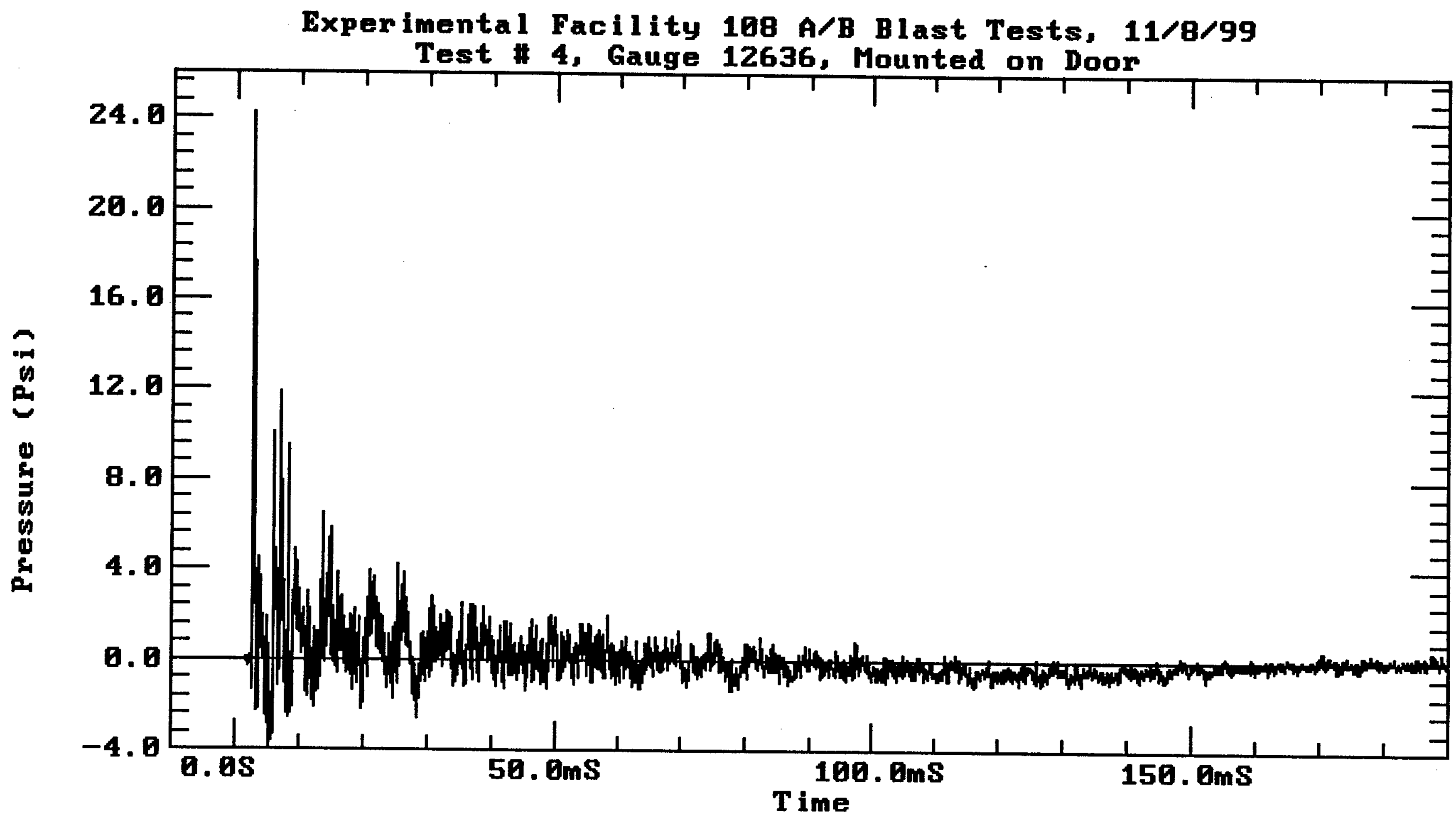

Figure 25. Test 4 long duration time history of pressure gauge mounted on door.

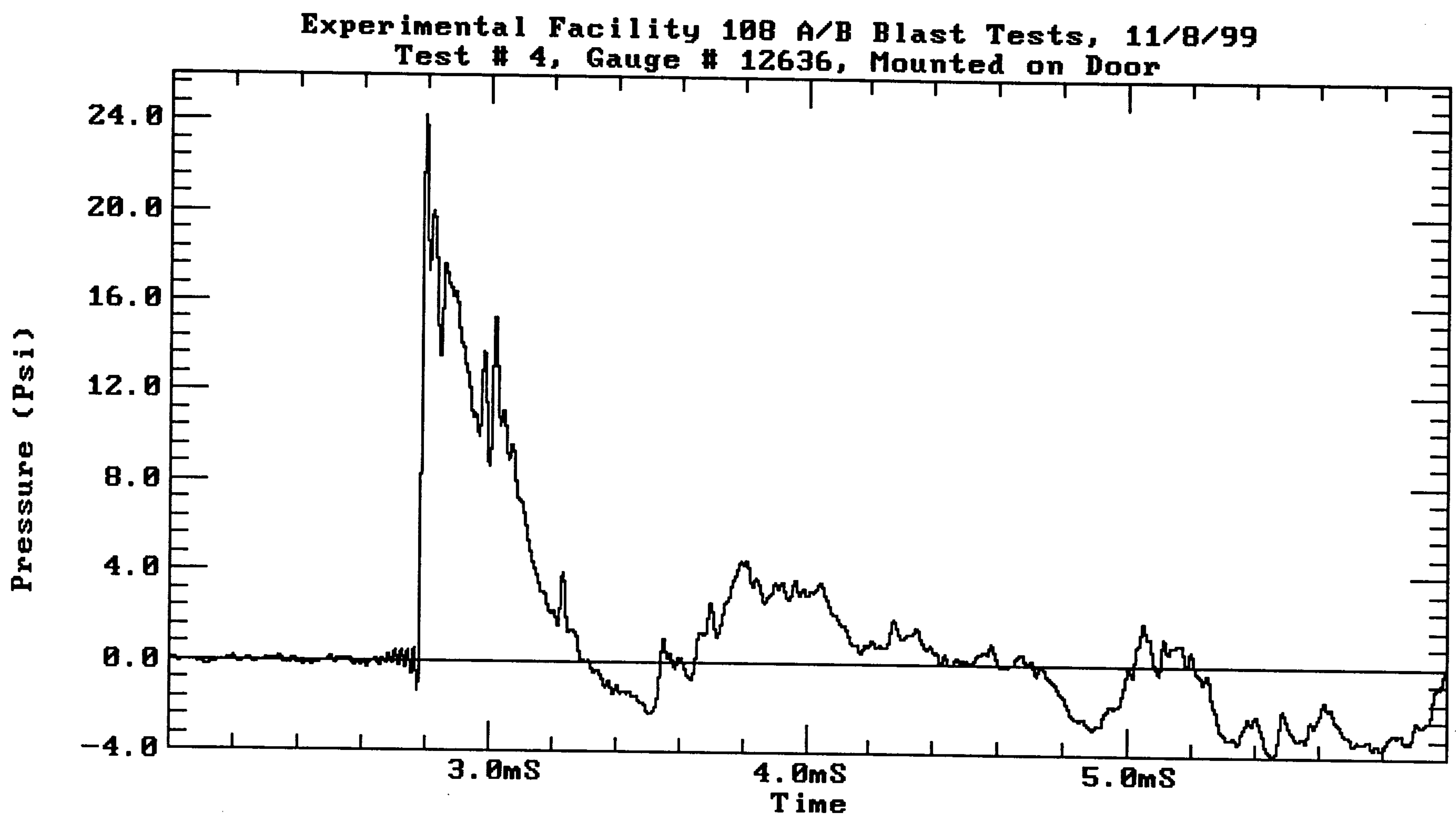

Figure 26. Test 4 short duration time history of pressure gauge mounted on door.

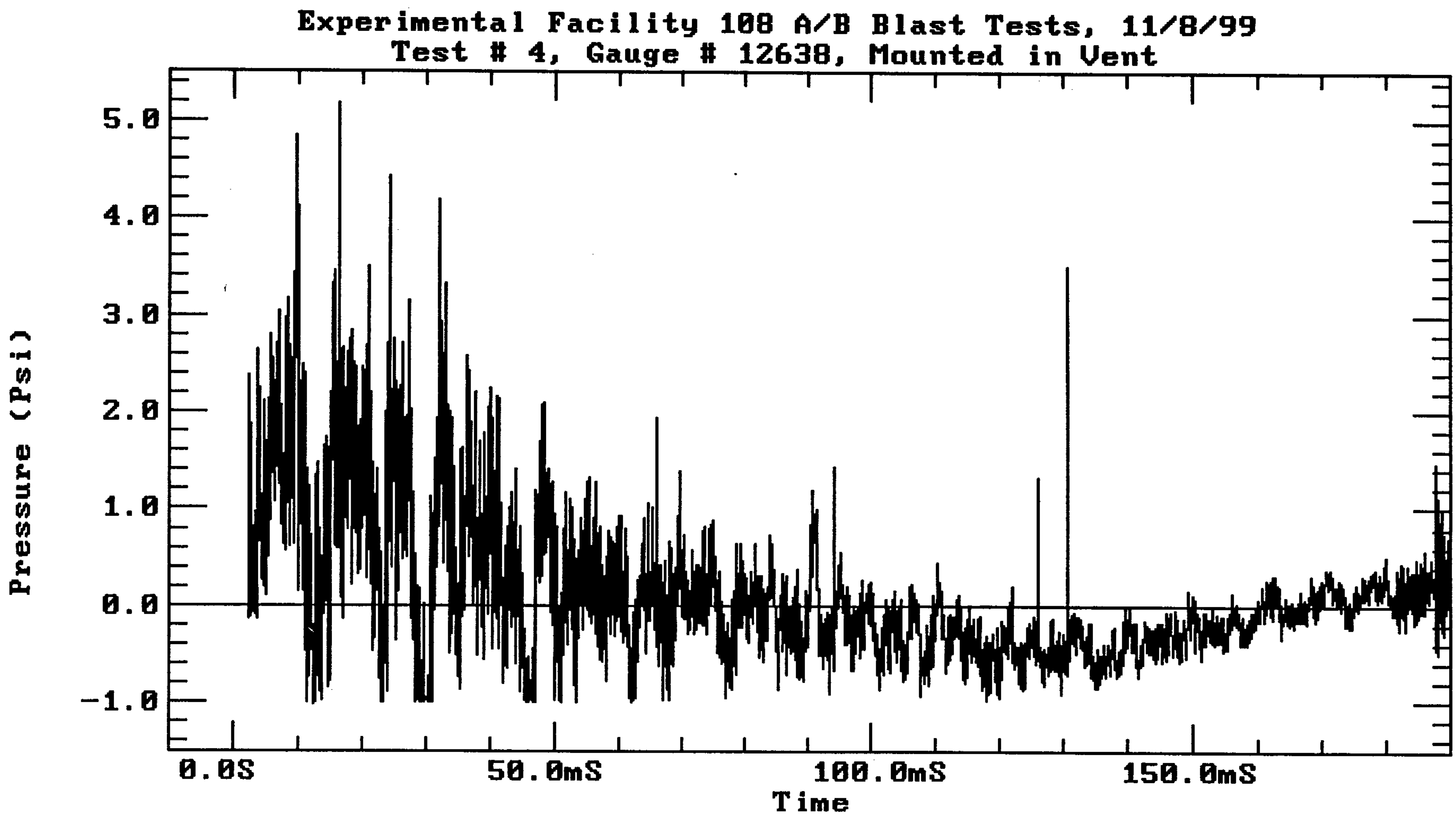

Figure 27. Test 4 long duration time history of pressure gauge mounted in vent.

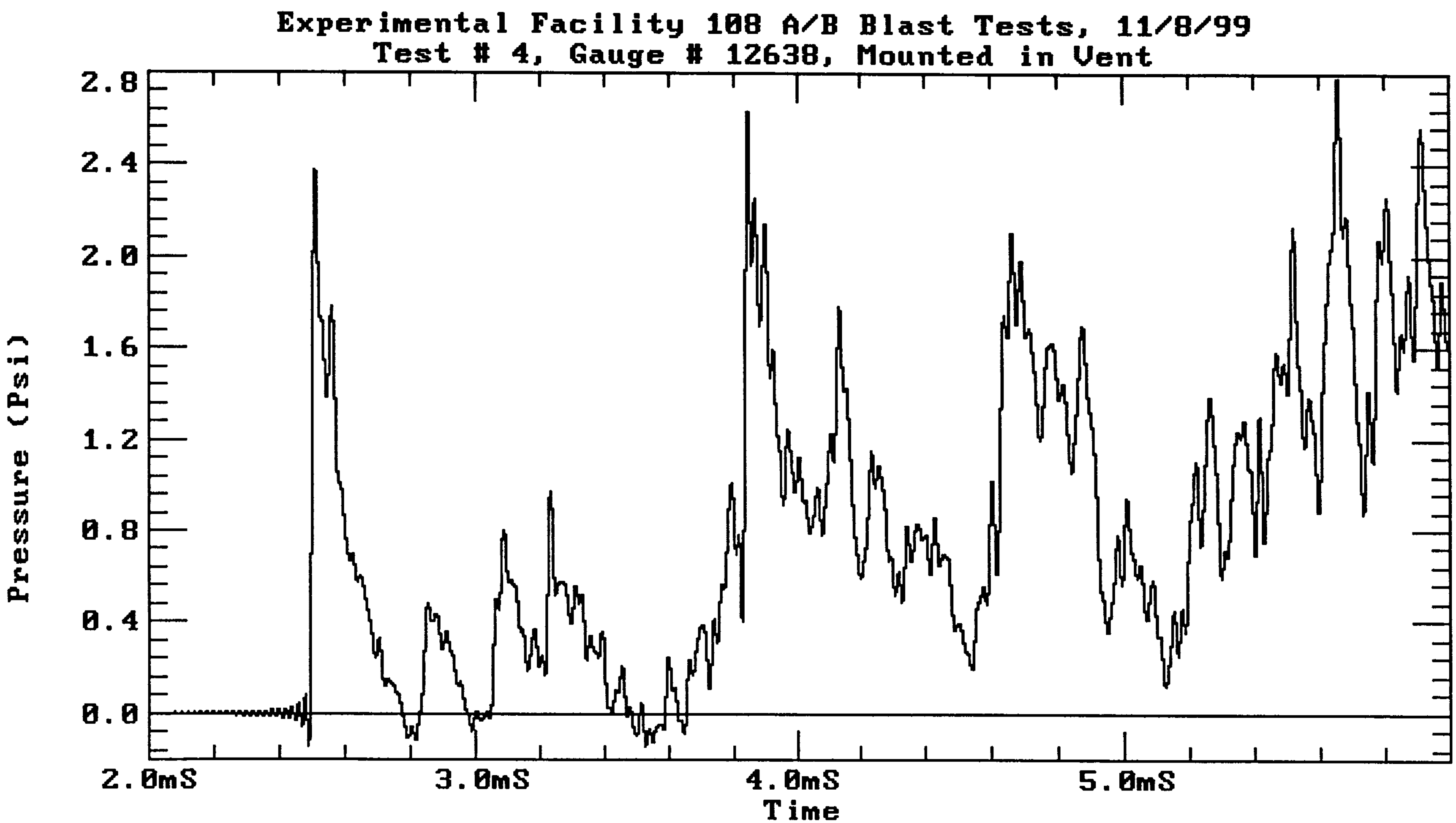

Figure 28. Test 4 short duration time history of pressure gauge mounted in vent.

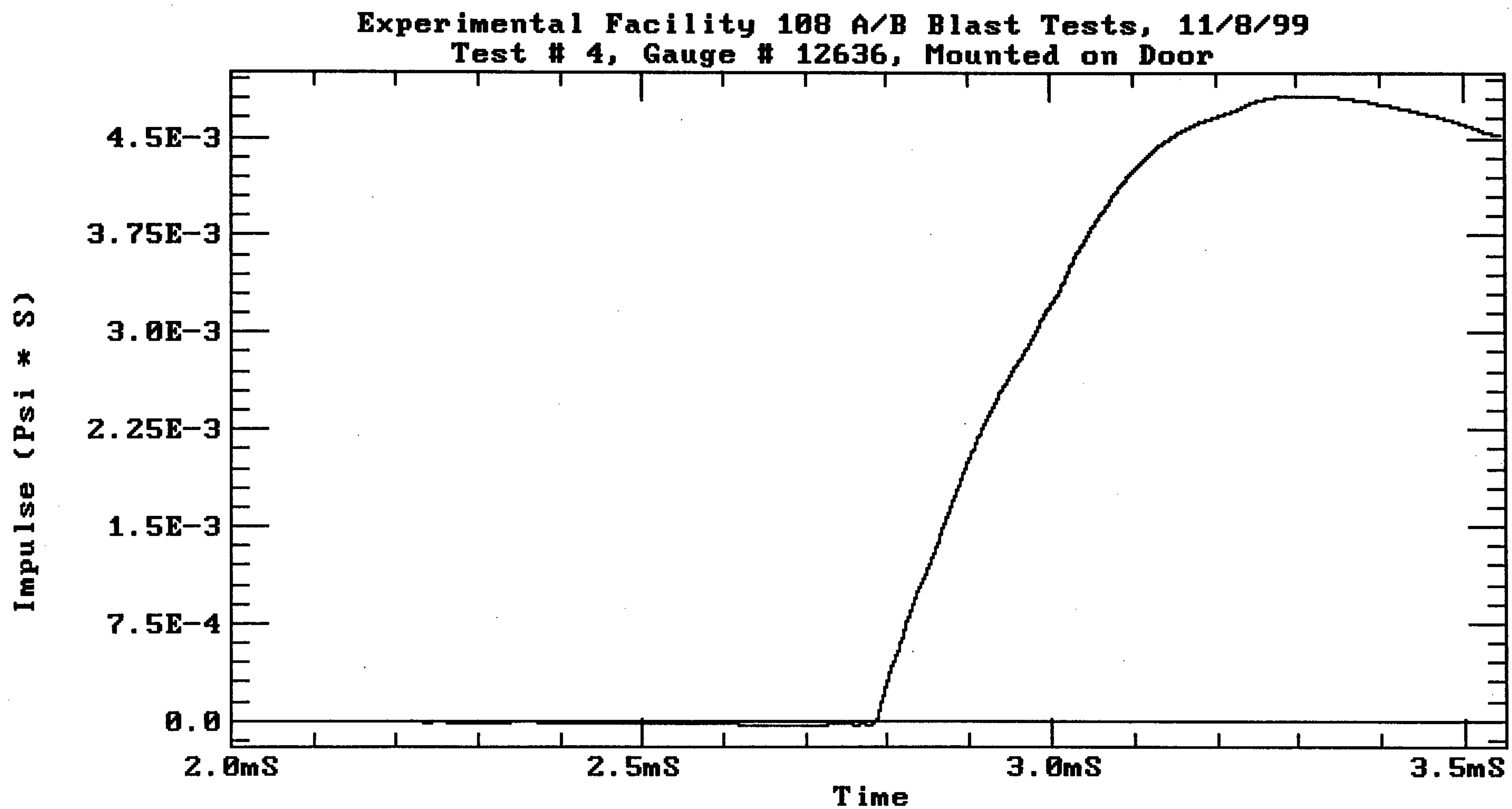

Figure 29. Test 4 impulse measured at the door.

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Appendix:

Transducer and Mount Specifications

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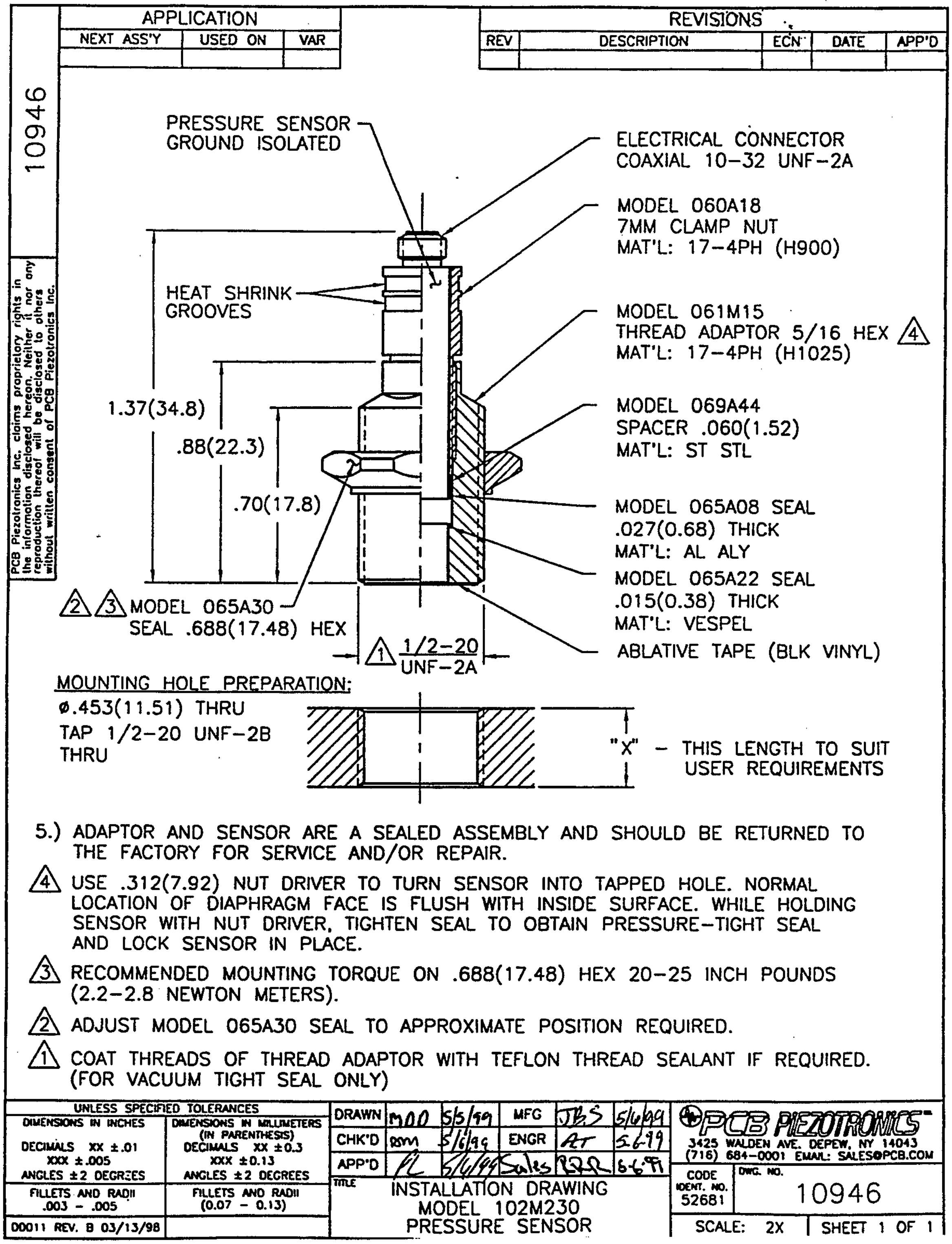


Figure A-1. Engineering drawing of PCB 102M230 pressure gauge.

Model Number 102M230	ICP® PRESSURE SENSOR			Revision: ECN #:

DYNAMIC PERFORMANCE			
Dynamic Range (for ±5V output)	psi [kPa]	1,000 [6 895]	
Useful Overrange (for ±10V output)	psi [kPa]	2,000 [13 790]	[2]
Maximum Pressure	psi [kPa]	10,000 [68 950]	
Resolution	psi [kPa]	0.02 [0,138]	
Resonant Frequency	kHz	≥500	
Rise Time	μ sec	≤1	
Low Frequency Response (-5%)	Hz	0.005	
Linearity	% FS	≤1	[1]
ENVIRONMENTAL			
Acceleration Sensitivity	psi/g [kPa/m/s²]	≤0.002 [≤0,0014]	
Operating Temperature Range	°F [°C]	-100 to +250 [-73 to +121]	
Temperature Coefficient of Sensitivity	%/°F [%/°C]	≤0.03 [≤0,054]	
Maximum Flash Temperature	°F [°C]	3,000 [1 649]	
Maximum Shock	g pk [m/s² pk]	20,000 [196 140]	
ELECTRICAL			
Sensitivity	mV/psi [mV/kPa]	5 ±0.25 [0,725 ±0,036]	
Output Polarity (positive pressure)		Positive	
Discharge Time Constant (at room temp)	sec	≥100	
Excitation Voltage Required	+ VDC	20 to 30	
Excitation Constant Current Required	mA	2 to 20	
Output Impedance	ohms	≤100	
Output Bias Voltage	+ VDC	8 to 14	
Ground Isolation	ohms	10^8	
MECHANICAL			
Structure	geometry	Compression	
Sensing Element	material	Quartz	
Case	material	Stainless Steel	
Diaphragm	material	Invar	
Sealing	type	Epoxy	
Weight (w/clamp nut)	oz [gm]	0.70 [20]	

OPTIONAL VERSIONS

Optional versions have identical specifications and accessories as listed for the standard model except where noted by the letter prefixes below. More than one option may be used.

☐	H	Hermetic Seal Sealing	type	Welded, Hermetic
☐	N	Negative Output Polarity (for positive pressure)		
☐	S	Stainless Steel Diaphragm	material	316L Stainless Stee
☐	W	Waterproof Connection for Attached Cable		

NOTES:
[1] Zero-based, least-squares, straight line method.
[2] For +10V output, minimum 24 VDC supply voltage required. Negative 10 volt output may be limited by output bias.

SUPPLIED ACCESSORIES:
Model 065A30 Seal

All specifications are at room temperature unless otherwise specified.

ICP® is a registered trademark of PCB Piezotronics, Inc.

In the interest of constant product improvement, we reserve the right to change specifications without notice.

Drawn: JF	Engineer: AET	Sales: RRR	Approved: [illegible]	Spec Number
Date: MAY5,'99	Date: 5-6-99	Date: 5-6-99	Date: 5/6/99	10944

PCB PIEZOTRONICS™ 3425 Walden Avenue, Depew, NY 14043 800-828-8840 Fax (716) 684-0987 E-Mail: sales@pcb.com

Figure A-2. Manufacturer's specification sheet for 102M230 pressure gauge.

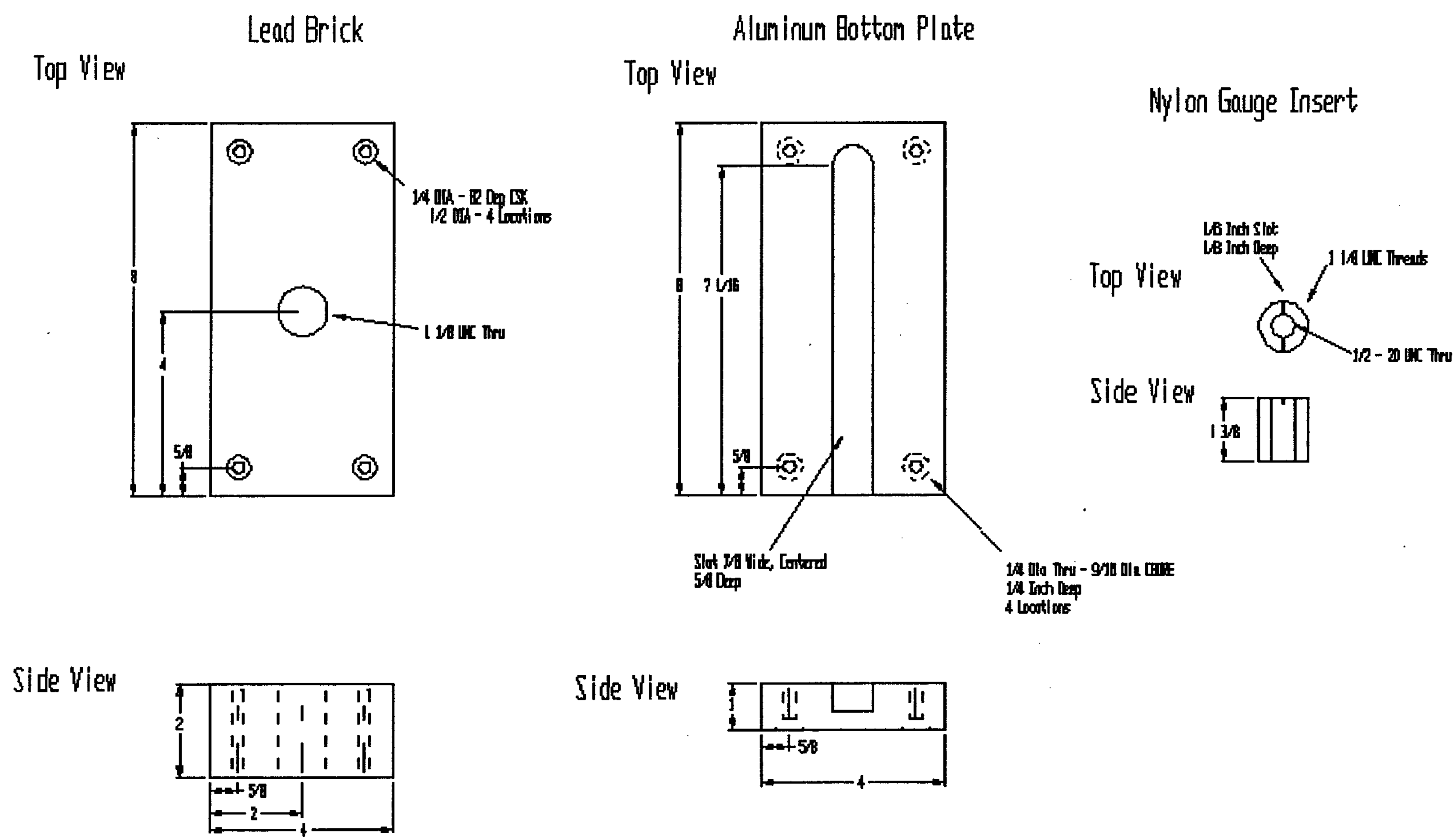


Figure A-3. Engineering drawing of lead "pig" pressure transducer mount.

PCB PIEZOTRONICS

CALIBRATION CERTIFICATE

Model: 102M230
Serial #: 12636
Description: Pressure Sensor
Type: ICP

Nat'l Freq: 500 kHz

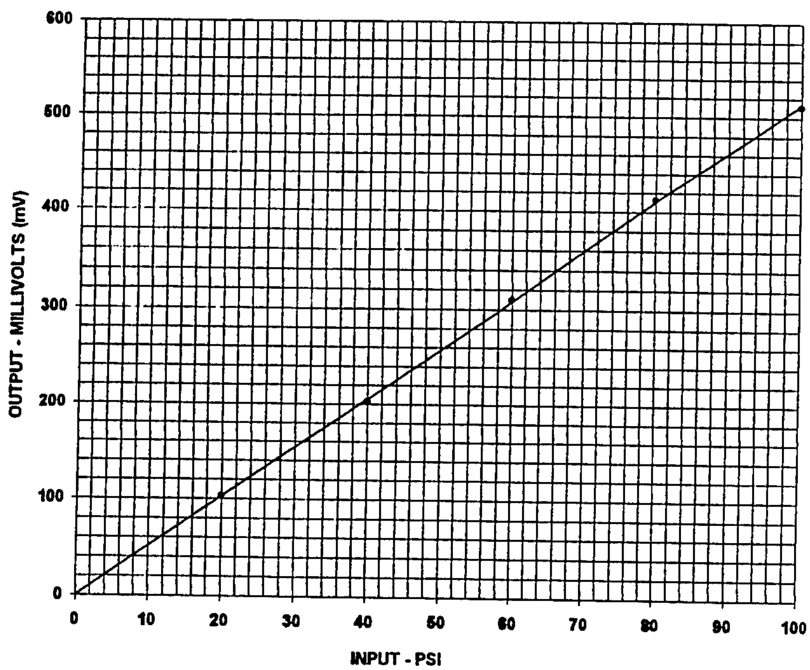
Date: 5/4/99
By: Tom Johnston, Cal. Tech. 70
Station: Dead Weight #1

Sensitivity*: 5.133 mV/PSI
Linearity*: 0.46% FS

Cert #: 32929

Bias: 9.9 VDC
* Zero based, least-squares straight line.

Notes:
1 Calibration is traceable to NIST and complies with ISO 10012-1 and former MIL-STD-45662A.
2 NIST traceability through project # 822/255136-95
3 This certificate may not be reproduced, except in full, without written approval.



TEST DATA

INPUT (PSI)	OUTPUT (mV)
20	103
40	203
60	310
80	413
100	511

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3425 Walden Avenue, Depew NY 14043
Tel: 716-684-0001 Fax: 716-684-0987
Email: sales@pcb.com Web: www.pcb.com

ISO 9001 CERTIFIED

Figure A-4. Calibration sheet for pressure transducer mounted on door.

PCB PIEZOTRONICS

CALIBRATION CERTIFICATE

Model: 102M230
Serial #: 12638
Description: Pressure Sensor
Type: ICP

Nat'l Freq: 550 kHz

Date: 5/4/99
By: Tom Johnston, Cal. Tech.
Station: Dead Weight #1

Sensitivity*: 5.158 mV/PSI
Linearity*: 0.45% FS

Cert #: 32937

Bias: 9.9 VDC
* Zero based, least-squares straight line.

Notes:
1 Calibration is traceable to NIST and complies with ISO 10012-1 and former MIL-STD-45662A.
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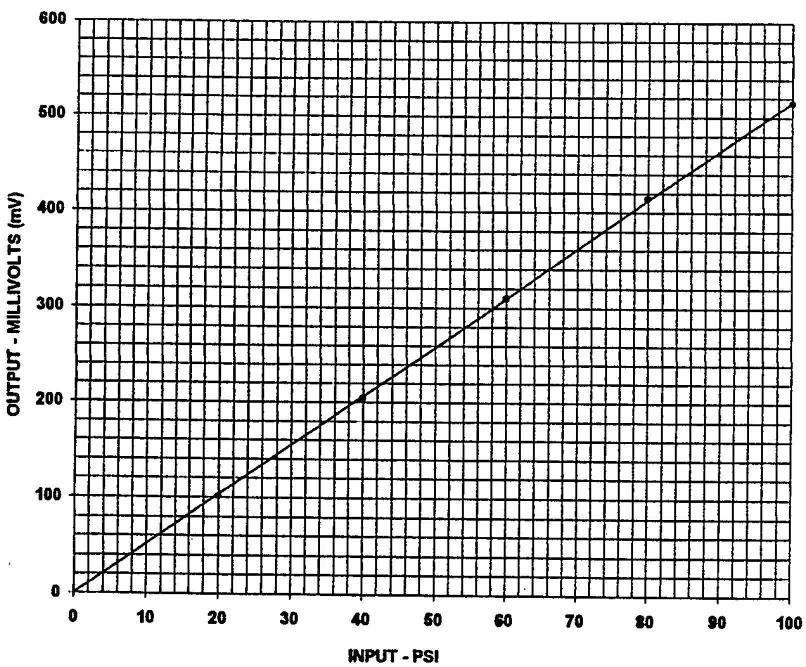
3 This certificate may not be reproduced, except in full, without written approval.



TEST DATA

INPUT (PSI)	OUTPUT (mV)
20	101
40	204
60	310
80	415
100	515

PCB PIEZOTRONICS, INC.
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Figure A-5. Calibration sheet for pressure transducer mounted in vent.

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1	OSD OUSD(A&T)/ODDDR&E(R) R J TREW THE PENTAGON WASHINGTON DC 20301-7100
1	DPTY CG FOR RDA US ARMY MATERIEL CMD AMCRDA 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	INST FOR ADVNCD TCHNLGY THE UNIV OF TEXAS AT AUSTIN PO BOX 202797 AUSTIN TX 78720-2797
1	DARPA B KASPAR 3701 N FAIRFAX DR ARLINGTON VA 22203-1714
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1	DIRECTOR US ARMY RESEARCH LAB AMSRL CI AI R (RECORDS MGMT) 2800 POWDER MILL RD ADELPHI MD 20783-1145
3	DIRECTOR US ARMY RESEARCH LAB AMSRL CI LL 2800 POWDER MILL RD ADELPHI MD 20783-1145
1	DIRECTOR US ARMY RESEARCH LAB AMSRL CI AP 2800 POWDER MILL RD ADELPHI MD 20783-1197
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The Impact Physics Branch of the Terminal Effects Division of the Weapons and Materials Research Directorate (WMRD), U.S. Army Research Laboratory (ARL), was tasked by the Armor Mechanics Branch, WMRD, ARL, to perform blast measurements in ARL Experimental Facility 108 A/B. This memorandum report briefly summarizes the results of four blast tests that were conducted on 8 November 1999. The purpose of this test program was to measure the blast pressure exhibited on various walls of the experimental facility's chamber (108A) as a result of the detonation of various size spheres of Detasheet and to determine the maximum explosive weight that could be used in this facility without extensive modifications.

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